UNIVERSITY OF CANTERBURY

Native Forest Monitoring

Tracking changes in Native Forest Remnants

A dissertation submitted in partial fulfilment of the
requirements for the degree of Bachelor of Forestry Science
with Honours by:

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Abstract

Native forest monitoring is undertaken by forest companies as a requirement for certification of their forests by groups such as the FSC. It is important for companies to be able to track changes that are occurring to native forest remnants that are often spread throughout their operational plantation forest estate.

Pan Pac tasked me with completing their 2016 native forest monitoring programme and review the results that have been collected since the programme was implemented in 2002. The objective of this was to both gain a better understanding of how the composition of the remnants in their5 estate is changing and to make recommendations on how the programme could be improved in the future.

The majority of the 11 Permanent Sample Plots (PSPs) measured were in good or stable condition, several of which showed strong regeneration of the understory over the past 14 years. Three of the sites have been affected by heavy ungulate browsing (deer and/or goats), which has resulted in the continued suppression of the understory vegetation. While all current canopy layers of the PSP have not changed significantly, current and future disturbance such as ungulate browse could result in a change in composition from the current forest makeup.

Ungulate browsing has been identified as the biggest driver of change in the native forest remnants within Pan Pac's estate. To further examine to magnitude of this, exclosure plots could be established in impacted remnants to assess the effect of removal of browsing pests as a basis for Pan Pac to make decisions about future ungulate control. Continued monitoring of native forests is key to be able to identify as well as understand what is happening with native forest remnants. Tracking composition change is important as it allows the forest manager to target management practices such as ungulate control to combat non-natural changes that are occurring.

Key Words: Native Forest Monitoring Remnant Floristic Composition PSP Permanent Sample Plot

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I have a great appreciation for David Norton who has been a great supervisor and always has answered the questions I have had. Thanks to the University of Canterbury School of Forestry as well as Luis Apiolaza for the chance to complete a dissertation project.

The students that are in the final year of the BForSc degree have been great mates over the last 4 years. I have really enjoyed spending my time at University with them and have created memories that will last a lifetime. This project has been a good way to finish the last semester off but I am looking forward to starting work in the industry as much as the rest of the class.

Table of Contents

1. Introduction

Native forest monitoring is an important task for forestry companies and is one of the requirements for attaining and maintaining FSC accreditation. As a part of forest operations, certified forestry companies establish and maintain a monitoring regime for their native remnants. As well as collecting data from the monitoring plots it is important to understand what the information being gathered tells us about how native remnants are changing. This understanding is often lacking as it is difficult to track changes in native forest composition.

Pan Pac Forest Products Ltd (Pan Pac) implemented a Native Area Monitoring Program in 2002 with the establishment of 11 Permanent Sample Plots (PSP's) after an initial course survey of their native forest remnants. The goal was to assess if the health of the native forest remnants that remained in Pan Pac's forest estate was changing and why. This was assessed by measuring the biodiversity present in the PSP's (focusing on forest composition and structure) at regular intervals; the plots were re-measured in 2006, 2011 and again this year in 2016.

The research described in this dissertation assesses the data that has been collected from these PSPs since 2002 and asks what it tells us about how the composition and structure of the native vegetation has changed. In the past a simple summery analysis has been conducted after each re-measurement, but this report will look further into the data using ordination analysis to view how the floristic composition of each of the PSPs has changed over the 14-year monitoring period. This will provide a more in-depth understanding on how as well as why the remnants in which the PSPs are located are changing.

Pan Pac wants to gain a better understanding of the data they have been collecting over the last 14 years. This is both to better fulfil the environmental requirements around their FSC certification as well as to inform management aiming to improve the quality of the remnants in their estate. This has become more important with the return of ownership of the Crown Forest Licence land to Iwi. While the Crown has been an absentee landlord in the past Iwi want to be more involved with the management of their land.

2. Problem Statement

Pan Pac have asked for a more in-depth analysis of their current native forest monitoring programme. It has not had a full review since its creation back in 2001/2002. As a part of this I was tasked over the summer with completing the 2016 survey for the programme as part of my summer work for the company. The following questions were devised to be able to provide the information Pan Pac are currently interested in, and in doing so, to provide recommendations on how the programme could be improved in the future. This review will assist the company fulfil its requirements under FSC certification as well as their environmental responsibility for the land they are custodians for. Without monitoring of native forests, degradation is hard to detect and remedial action may be too late to be of use (Handford, 2000). To this end I am looking at answering three main questions with this dissertation project:

-What information does the data that has been collected provide?

-What does the monitoring tell us about the remnants in which the PSP are located, especially how they have changed over the monitoring period?

- How can the monitoring program be improved in the future to better meet FCS requirements?

3. Literature Review

In this literature review I focus on four main areas that I have identified as providing the basis of a better understanding on the results that have come out of the native forest monitoring program. In addition, this review will assist in providing insight into potential improvements to monitoring activities.

What is native forest monitoring? Monitoring is the assessment of change in specific characterises such as floristic composition over time or between areas (Handford, 2000). For Pan Pac's programme this is in relation to the characteristics in the understory as well as the canopy layer, identifying the plant species present as well as the amount of invasive pest damage to the sites.

The initial setup of the native forest monitoring programme undertaken by Pan Pac was greatly influenced by the book "Native Forest Monitoring" (Handford, 2000). The section on "Quick plot method for vegetation assessment" providing the basis for both the plot layout as well as the original plot forms. This was combined with personal communication with Peter Handford as well as David Norton to help design a programme that would matched Pan Pac's needs and achieved the goals of the programme.

3.1 Permanent sample and exclosure plots

The PSP layout for Pan Pac's monitoring program is not standard, but the size is. The 0.04 ha size is a common standard across New Zealand but is normally made up of 20x20m square plot (Allen, 1993) compared to the 50x8m transect used in Pan Pac's monitoring program. The purpose of a permanently located PSP is to be able to detect any long term changes in forest structure or composition for the same place (McNutt, 2012).

After reviewing the process that has been outlined for both PSP assessments approaches, the methods are similar but have differences that make comparison difficult. The canopy count is done for both methods over the same area but thresholds for canopy trees are different, 10cm used is Pan Pac's current method compared to 2.5cm for the standard method (Allen, 1993). This would result in more trees being included in the canopy than using the standard method. All saplings are counted in the 20x20m plot compared to the current 5 sub-plots (4m^2 each, 20m^2 total), this would result in a much more accurate estimation of the sapling layer in the plot, but is more time-consuming. Using the standard method the understory seedling composition is assessed using 24 sub-plots (0.75m^2 each 18m^2 total) compared to the current 5 sub-plots (1m^2 each, 5m^2 total), this could have a comparable area but only woody seedlings are counted rather than all in the current method (Allen, 1993). During the initial setup of the program there was the assumption that using a 0.04ha plot size would allow for the comparison of PSP to the standard national data base, but with the different in collection methods it would not be a fair and accurate comparison to other 0.04ha PSPs located in the region. While the 20x20m method would produce a more accurate and comparable result, there would be an increase in the cost of monitoring as the time required to survey each plot would go up.

PSPs are used to both study change in composition driven by natural factors and/or driven by animal pests browsing on the understory or canopy layers. To make this assessment, exclosure and unfenced permanent plots would be needed. Exclosure studies have showed what happens when pests have been excluded from an understory, with a wide variety of forest types being studied. The advantage of using exclosure plots is that they allow you to assess how the vegetation would respond if animals were completely removed, to estimate what the impact of browsing animals might be. This method of comparison has resulted in a better understanding of the impact that pests are having on native forests (McNutt, 2012). Another often unseen effect of pest browsing is in the forest floor with changes seen in the composition of the leaf litter and therefore the litter-dwelling faunal groups (Wardle et al, 2001)

Unfenced PSPs allow for a sample survey of the current conditions in a particular remnant, compared to fenced PSP which exclude pests. The main disadvantage of fenced plots it that they are expensive to set up and maintain, needing regular inspection to prevent pest entry. Exclosure plots would allow for the assessment of pest impact on Pan Pac's native forest remnants and would allow for the better targeting of pest control activities. (Basis for discussion (Husheer, Coomes, & Robertson, 2003))

3.2 Disturbance of Native Forests

Disturbance is the biggest natural driver of composition change in New Zealand's native forests. Large disturbance over wider areas coming from catastrophic events such as earthquakes, landslides or volcanic eruptions. As well as the much more common small scale disturbance coming from tree wind throw during storm events, or small gaps created when older trees die (Hill & Read, 1996). Forest composition and structure are strongly influenced by the disturbance history in an area. Any changes that are visible in a native forest related to composition or structure of a native forest occur over an extended period of time (Bellingham et al. 2000). Linked in with the slow growth of native trees and the suppression of the understory layers by a canopy until gaps are created by disturbance. More frequent disturbance of an area can lead to different species coming through compared to a less disturbed forest, even if both areas started out in the same forest type (Enright & Hill, 1995).

Disturbance create gaps in the canopy layer of a native forest, this increases the light available to the understory layers which triggers growth and succession to replace the trees that have been lost. With the understory sapling layers suppressed until gaps are created. Forests are maintained by disturbance, with times of regeneration followed by short periods of collapse (Enright & Hill, 1995). Beech forest stands can have large disturbance events every 120-150 years, with smaller disturbance happening every 20-30 years (Hill & Read, 1996). This disturbance driven change has occurred naturally for thousands of years, before large mammal browsing pests were introduced to New Zealand.

3.3 Pest presence in Native Forests

The introduction of pests to an area can cause significant damage to native forest remnants and lead to the degradation of an area's ecological values (Porteous, 1993). High pest presence in native forest results in a change in in how a forest behaves. Studies into the effect of deer populations on beech forest has shown increases in unpalatable species with the reduction of palatable species reaching sapling size (+75cm). Deer were shown to disrupt the normal successional process and led to the recommendation of an increase in the deer control (Husheer, Coomes, & Robertson, 2003). High browsing can lead to the decrease of palatable species in a forest which leads to increase in non-palatable species as they are able to spread with less competition and browsing (Salmon, 1996).

The reduction of pest numbers in a forest can often lead to the emergence of a different plant succession, especially if an area has been suppressed by browsing for an extended period of time (Salmon, 1996). In the Kaweka Range Hawkes Bay, the influence of browsing animals has been shown to have affected the dynamics of the mountain beech forests. With an average reduction of 2.5% in basal area in the 30 plots studied over a 14-16 year period, with reductions in average tree diameter but increases in stem numbers. Along with very low density of mountain beech seeding and saplings. Allen & Allen (1997) concluded that browsing deer were having a detrimental influence on the composition of beech forest in the area, with the majority of the sites showing that regrowth would not be sufficient to maintain a complete cover of canopy in the future. Recommending that increased pest control would be needed by the Department of Conservation if that the effects were to be reversed (Allen & Allan, 1997). This study is very relevant to two of the beech forest PSP sites which are located in Pan Pac Kaweka forest where high pest number have been present for a number of years.

The assessment of pest presence during the survey has been based on observations through and around each plot. Looking for faecal pellets, browse damage as well as tracks on the ground, but there has been no specific push to identify animal numbers. Several papers have specified ways to calculate pest presence in an area, mainly focusing on systematic methods to cover a much larger area than the plots used by Pan Pac (Baddeley, 1985). Assessing pest presence over a larger area allows for the identification of the movement of pests through an area and would help show the effect of control effort on an area. But if a more in-depth method was used in the future by Pan Pac it would require a larger input of time to the monitoring program and covering larger areas just for pest presence would be infeasible looking at some plants outlined in reports (Baddeley, 1985). Adding to this past estimates would not be able to be used as a comparison if an improved technique for monitoring was implemented, unless both techniques are used on several site at the same time to form the comparison.

While larger mammals can be monitored through looking for obvious browse damage, faecal pellets and tracks, smaller pests such as possums, rats and stoats are harder to assess. Pan Pac do have a trapping program in their forests both to monitor and reduce pest numbers (Pan Pac, 2016).

3.4 Effects of plantation management on Native Forests

Research has shown that when native remnants are bordered by plantation forest the plantation provides a valuable microclimate buffer to the edge of the remnant (Denyer, Burns, & Ogden , 2006), producing conditions similar to that of the interior of larger native remnants, reducing light and temperature when compared to remnants that are bordered by pasture. However, when the plantation stands surrounding native forest remnants are harvested this opens up the edges of the remnants to higher temperatures and the effect of wind, but any effect would only occur on the edges of remnants and would only last until the replanted plantation grew to a size to again provide protection to the remnant (< 10 years). Plantation forests can also improve connectivity between remnants, allow mobile species such as birds to move between remnants (Norton, 1998).

4. Method

4.1 PSP data collection

During the initial establishment of the monitoring programme in 2002 the process for data collection for the PSPs was established. Initial work by Pan Pac in 2001/2002 resulted in all native forest remnants in their estate being classified by forest type. From this a series of 51 plots were established throughout the native areas to provide a coarse level ecological survey (Pan Pac, 2016). Based on this, 11 PSPs were established to monitor native forest composition and were chosen to be roughly proportional to the main native forest types present. The PSPs are spread out in Pan Pac forest, Figure 14 in the appendix shows where they are located. Through collaboration with DOC as well as research into correct native monitoring practices the monitoring procedures were established, following the guidelines in (Handford, 2000).

The procedure for the monitoring plots is as follows:

-Plots comprised 50 m transects through the forest, 4 m either side of the centreline to produce a PSP covering 400m^2 (0.04 ha; Figure 1). 10 pegs marked out each plot, with 6 along the centre line and 4 marking out the corners of the transect plot. Within this 5 sub plots were established to measure the understory within the PSP, each laid out in front of and to the left of the centreline of the plot in 10m intervals (Figure 1).

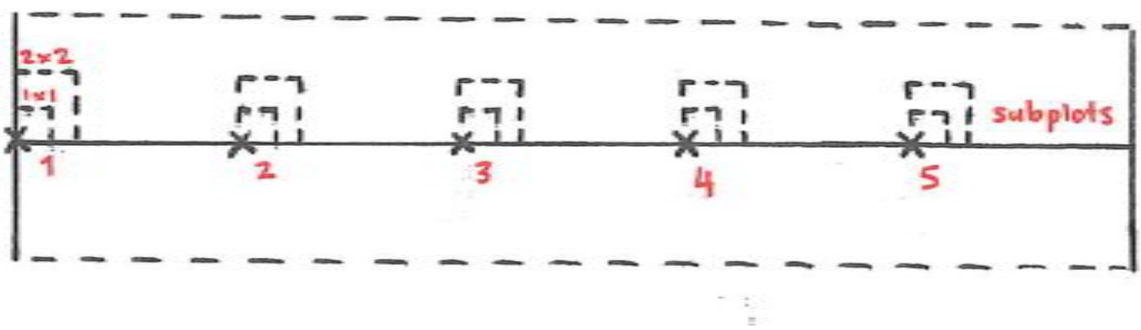

Figure 1: Sub-plot layout for each of the PSPs

-Canopy trees were classified as any native species with a dbh >10 cm. All canopy trees within the 50 x 8 m plot were tagged so that their growth could be tracked over the monitoring period. New trees would be tagged at each resurvey if their dbh exceeded the threshold, with dead canopy trees also recorded. Diameter was measured with the tape sitting on top of the tag nail.

-Saplings were classified as any native species >1 m in height and a dbh <10 cm. Saplings were recorded in the 5 subplots, each measuring 2 x 2 m. This allowed the monitoring to build up a picture of the sapling abundance without having to spend extended periods of time measuring all of the saplings in the whole PSP.

-Seedlings were classified as any native species that had a height <1 m. Seedlings were recorded in 5 subplots, each measuring 1 x 1 m.

-Pest presence was undertaken by looking for faecal pellets, browse sign and the animals themselves within the PSPs. The main browsing pests that are found within Pan Pac's estate are red deer, pigs, goats and possums.

Ferns have been excluded from the data collection because of the number of species that could be present and the difficulty that come with correct identification. Bird survey of 5 minutes was originally established with the program in 2002 but were discontinued for the 2016 survey and future surveys because of problems with the data. Counts are strongly influenced by the time of day each PSP was visited as well as weather conditions and an observers skills. They were therefore not considered an accurate measure of forest heath over time.

With the previous surveys in 2002, 2006 and 2011 being carried out following these guidelines I set out in the 2015/2016 summer to re-survey the PSP as a part of the 5 year monitoring process. This work was completed in and around other jobs I did while at Pan Pac over the summer. Starting in late December 2015 the majority of the PSPs were measured post New Year. Each site took around half a day to complete depending on location and the density of the understory. While pegs did mark out each plot it was often difficult to find the plots having not visiting the sites before. To prevent this problem in the future I used a GPS to mark each of the 6 pegs that laid out the PSP. The high accuracy Trimble GPS collected several hundred points per peg to locate each one down to a sub 250 mm accuracy which would allow for the replacement of pegs if any did go missing in the future.

Through the use of the herbarium of native plants in the estate as well as several reference books on native plants I was able to quickly build up my knowledge and skills of plant identification. While I was not able to identify all species on site, where I was unsure I took samples along with pictures to allow for a correct identification back at the office. The survey of the understory took the most time with each PSP but there were other issues that did come up. Finding tags on the canopy trees was difficult if trees had died and fallen in the previous 5 years, which was compounded with windfall/ snowfall damage in one plot.

Plot sheets were filled out in the field before being entered into Excel for an electronic record of the result to be correlated and stored. All data sheets were placed into two ring binders where all original paper records of the monitoring are kept.

4.2 Previous Data Analysis

In past reports the PSP's have been ranked against each other for each of the different parameters recorded. I have decided not to focus on this as all the remnants of native forest are different, both in terms of composition and life cycle. This means the ranking does not truly reflect the value each piece of native forest has in Pan Pac's estate. The main comparisons have been done with the previous data collected in 2002, 2006 and 2011 for each of the PSP's in isolation from the others.

From the analysis of the data from the 11 PSP's eight graphs have been created so the differences between plots as well as years can be clearly seen. Data from all four survey years has been used; being able to understand how and why the forest has changed over time will help management staff to be able to sustainably manage the development of Pan Pac's native forest remnants.

After inputting the paper plots sheets into Excel for the 2016 survey I found a few discrepancies in the previous data/graphs. After going back over all of the plot sheets from the previous three surveys I found and corrected the errors which were due to incorrect entering of numbers into the computer. I also found some discrepancies while doing this in which species had been deemed to be palatable or not, to correct this I rechecked all the species against the original list, 2 species in the 2006 survey were interpreted as palatable when they were not.

4.3 Ordination

To complete the ordination analysis for this report, de-trended correspondence analysis was used. I re-entered the data from the original 2002 and the 2016 plot sheets. This involved entering all of the individual species and the numbers present rather than using a summary. This has allowed me to look at how the floristic composition of the plots has changed over the 2002-2016 time period. Ordinations were undertaken for seedling, sapling and canopy BA and compared floristic composition in each PSP between the 2002 and 2016 data sets.

The process compares each of the 11 PSPs to each other over the two periods. This shows how each of the plots has changed in comparison to both itself and all of the other plots. While completing the ordination analysis for the sapling count it was found that Karaka Rd site caused a problem with the analysis due to the fact that the only one sapling species was found at this site. Because of this the ordination would not run, and I removed this site from the sapling ordination for analysis. The outputs were replotted in Excel so the graphs could be interpreted for this report.

BA was used for the canopy ordination because it allows the growth of the previously tagged trees to be included in the analysis. Previously competed analysis manly focused on the understory, only using a count of the canopy rather than using the DBH information collected. Having the trees tagged has allowed the tracking of trees to occur through the years, identifying which have died.

In consultation with my supervisor, it was decided that the ordinations should only be undertaken for the 2002 and 2016 data because including multiple years would have become too complex. But the analysis has shown new information from the previous data, and has allowed for a more visual interpretation of how the PSPs have changed over the period.

4.4 PSP Sample Check

One of the issues that I wanted to check as a part of this dissertation was if the 11 PSPs are a representative sample of the native remnants in the Pan Pac estate. To do this I used the GIS mapping of the estate to calculate the total area in each native vegetation type. This was then compared to the current makeup of the PSPs in order to establish if further PSPs should be established to cover more of the estate if particular vegetation types have not being covered.

5. Results

To make sure the plots are correctly and more easily identified I have converted their closest road name, which had been previously used for identification, to a number. This will help with the flow in reporting the results. The names and their respective numbers are listed in Table 1 below.

Table 1: PSP site identification

Site	PSP Number
Wakarara Rd	1
Pickford Rd PSP 1	2
Pickford Rd PSP 4	3
Wakarara/Ellis Rd	4
Castle Rock Rd PSP 3	5
Castle Rock Rd PSP 4	6
Takere Rd	7
Paratu Rd	8
Karaka Rd	9
Papa Rd PSP 3	10
Papa Rd PSP 4	11

5.1 Pest Presence

Observations were made at each site in relation to pest sign/browsing evident in the plots. On the advice of Department of Conservation (DOC) staff however these observations were not relied on to draw specific conclusions about the existing pest population (numbers) as pests such as deer can be very mobile and leave little sign which does not accurately reflect the true number of animals present or their impacts. Rather pest sign/browsing evident in the plots was used to support findings relating to the regeneration of saplings from seedlings and also palatable species abundance and diversity. A summary of pest sign/browsing is given in Table 2 below.

Table 2: Pest presence observed during the 2016 survey

Pest Presence Observed by Monitoring Site		
Monitoring Site	**Browse Sign**	**Faecal Pellets**
1 - Wakarara Rd covenant	Nil	Nil
2 & 3 - Pickford Rd	Occasional-Deer	Nil
4 - Wakarara/Ellis Rd	Occasional-Deer	Nil
5 & 6 - Castle Rock Rd	Abundant-Deer	Abundant-Deer
7 - Takere Rd	Occasional-Deer	Occasional-Deer
8 - Paratu Rd	Common-Deer	Common-Deer
9 - Karaka Rd	Abundant-Goats	Abundant-Goats
10 & 11 - Papa Rd	Common-Possum	Nil

The PSPs that have been affected the most by pest browsing are 5 & 6 at Castle Rock as well as PSP 9. PSPs 5 & 6 have been effected by deer browsing for an extended period of time. PSP 9 has a very high goat population, and I was able to shoot 14 goats out of the remnant before completing the 2016 survey. Other sites have occasional browse damage but much less than these three sites.

As discussed in the literature review a more in-depth pest survey would be needed for an accurate estimate of pest numbers. This would include looking for pest presence in a wider area using a search grid as well as monitoring more regularly to assess where larger pests are spending longer periods of time. But approaches would show if pests have spent time in the PSP's and help provide better justification of some of the patterns seen here as described below.

5.2 Seedling Information

The seedlings provide the bank from which native forest can regenerate after disturbance of the canopy or sapling layers. Results from the understory survey show that this layer has experienced the most fluctuation over the years with sites changing both in seedling numbers as well as the composition of the seedling flora. This has made it harder to interpret the results compared to the sapling or canopy layers.

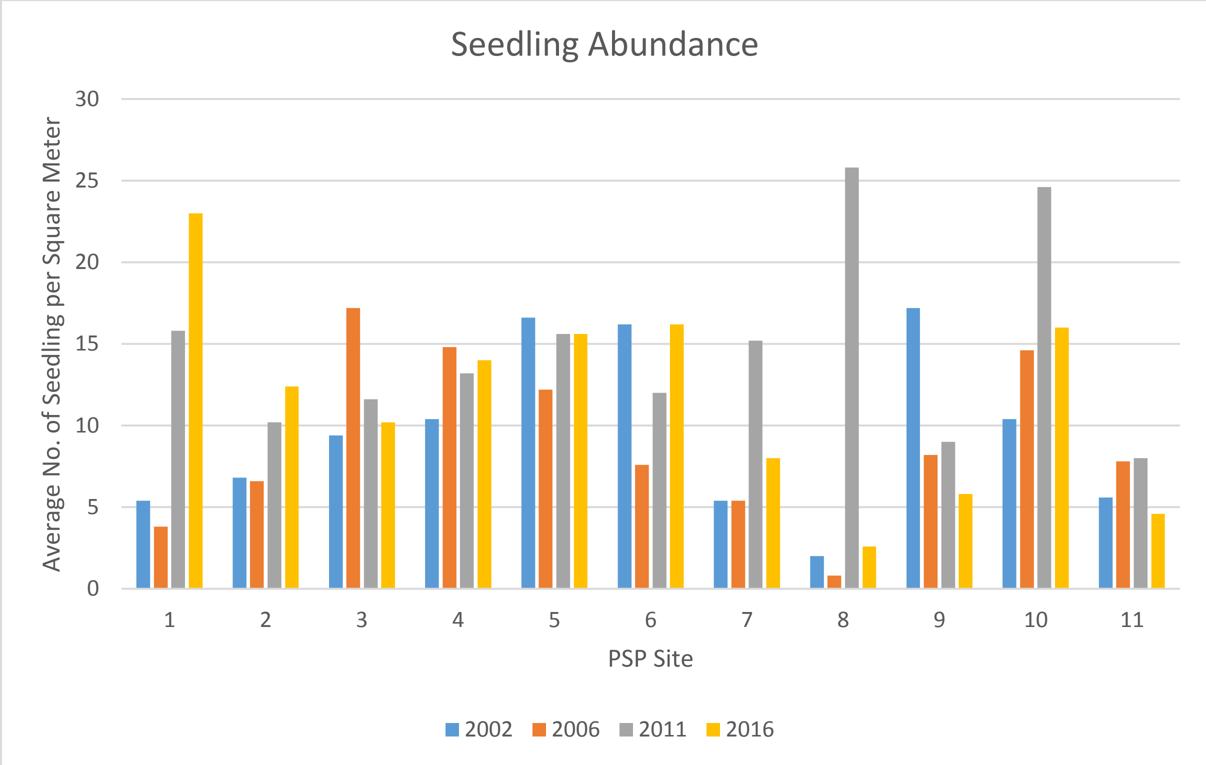

Figure 2: Seedling Abundance by PSP for all survey years

Looking at the general trends from the summary count shown in Figure 2, seedling abundance for six of the sites has increased or been steady. But PSPs 3, 7, 9, 10 and 11 show reductions in seedling numbers from the last survey. The drops in PSPs 10 & 11 are likely to have come about from the large increase in sapling number with seedlings moving into this height class. The long term drop shown after each survey at PSP 9 is likely to be the result of high goat browse reducing seedling numbers. PSP 8 stands out with a large spike in the 2011 survey, which has come about from a large number of small rimu seedlings at this site in that year, presumably resulting from a masting event, which did not survive through until 2016.

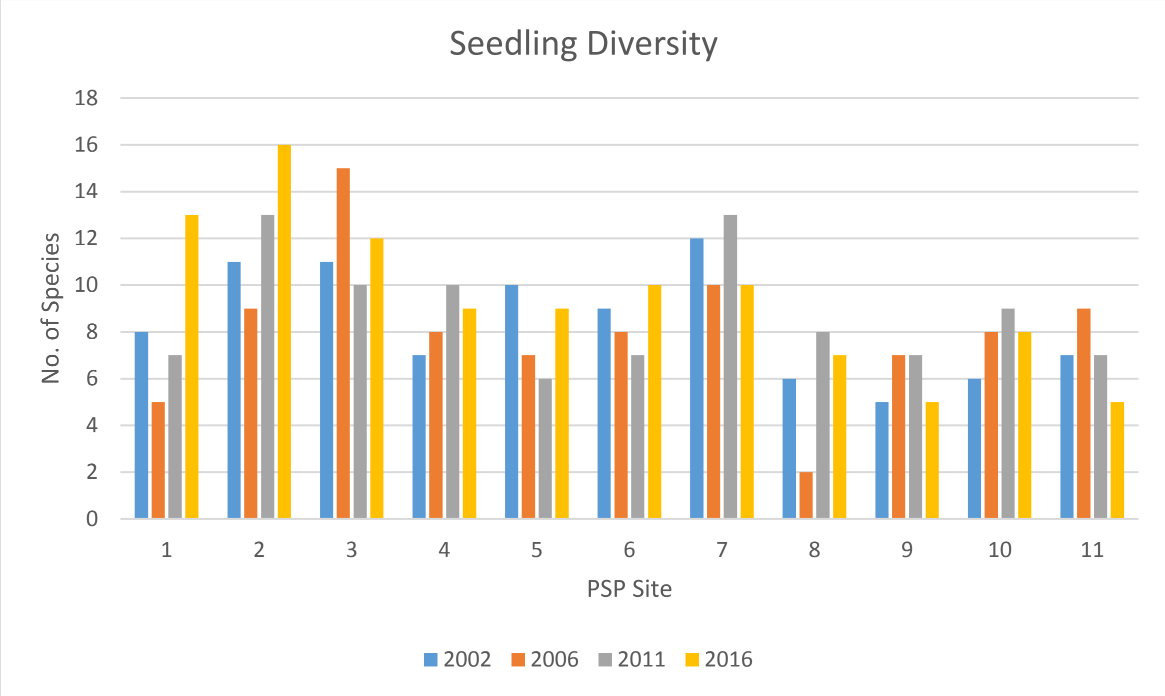

Figure 3: Seedling diversity by PSP for all survey years

The seedling diversity results follow a similar pattern to abundance, but with more variation in-between survey years making it difficult to pick out patterns. Looking at the overall trends PSPs 4, 5, 7 & 11 are showing drops in the number of seedling species present over the survey years. But there are a diverse species spread across all of the sites with a total of 60 different seedling species recorded in the 2016 survey.

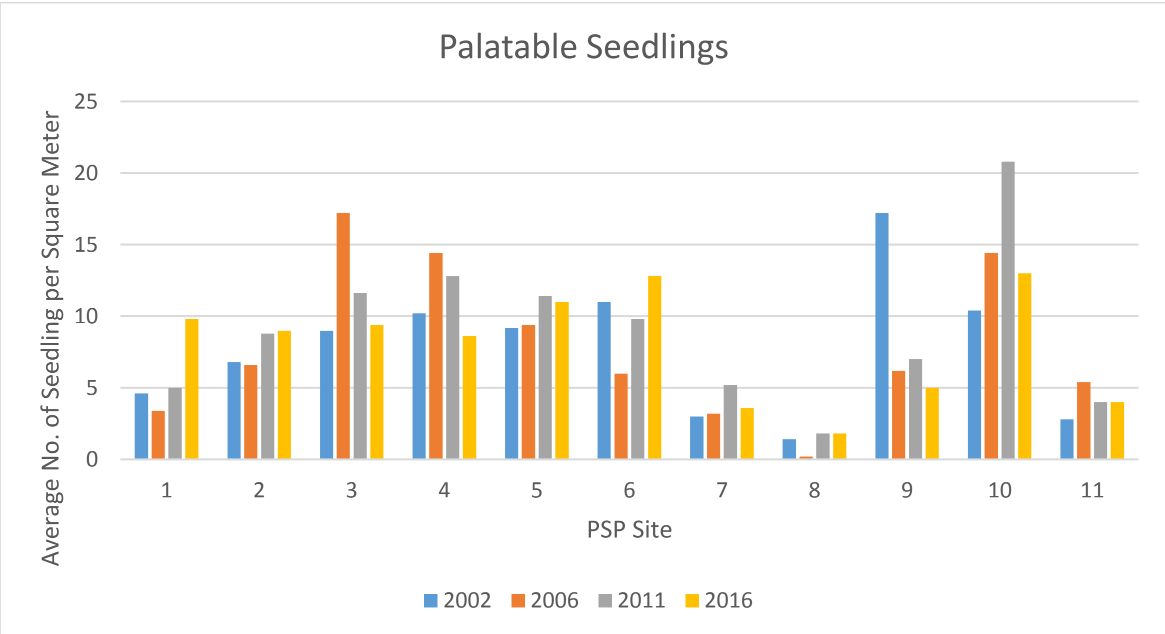

Figure 4: Average number of palatable seedling by PSP for all survey years

Figure 4 shows how palatable the seedling layers of each PSP are, overall there are a much higher number of palatable seedlings than saplings, because not all seedlings reach the sapling stage. PSPs 5, 6 & 9 show relatively high numbers of palatable seedlings but this is not continuing on to their sapling layers with the plants being browsed out and mainly non-palatable species growing through. PSPs 7, 8 & 11 show the lowest overall palatable seedling numbers.

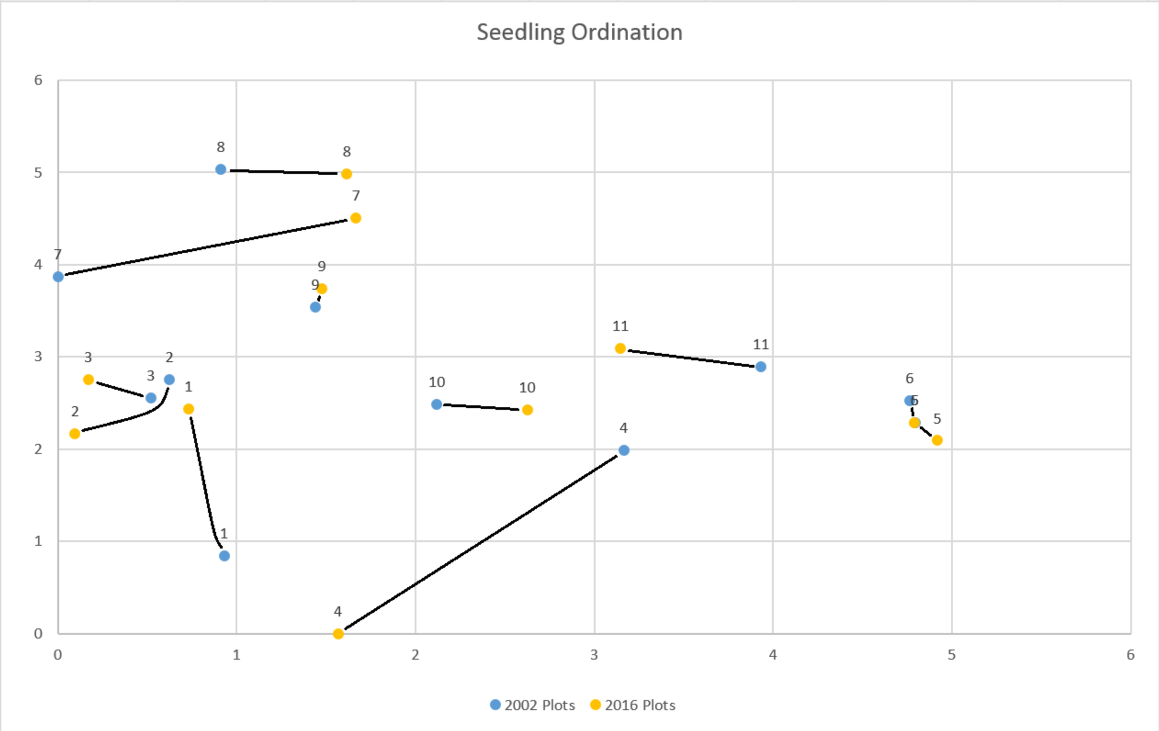

Figure 5: Seedling ordination by species between 2002 & 2016

The two largest changes in floristic composition of the seedling layer shown in Figure 5 are with PSPs 4 & 7.The seedling results for PSP 4 link in well with the regeneration seen in its sapling layer with several new species being introduced to the site. The change seen in PSP 7 does not link in with its sapling layer changes, this may indicate that the species have been introduce to its seedling layer but have yet to grow through to the upper understory. The high browsing at PSPs 5, 6 & 9 has resulted in a very low change in floristic composition in the seedling layers of these sites. The high browse is suppressing growth and the introduction of other palatable species into the remnants.

5.3 Sapling Information

Saplings in the understory play a key role in the regeneration cycle of native forest, as they represent the pool of individuals waiting in the understory until disturbance creates space for them to replace the canopy layer. From the abundance data shown in Figure 6 there have been increases in total numbers across nine of the PSPs, with the best overall gains have come from PSPs 4 and 10. Drops in sapling numbers have been seen at PSPs 1 and 9, PSP 1 has only had a small drop and is not a heavily browsed site. Compared to PSP 9 which was as still is effected by high goat browsing which is surprising the few sapling that do grow in the plot.

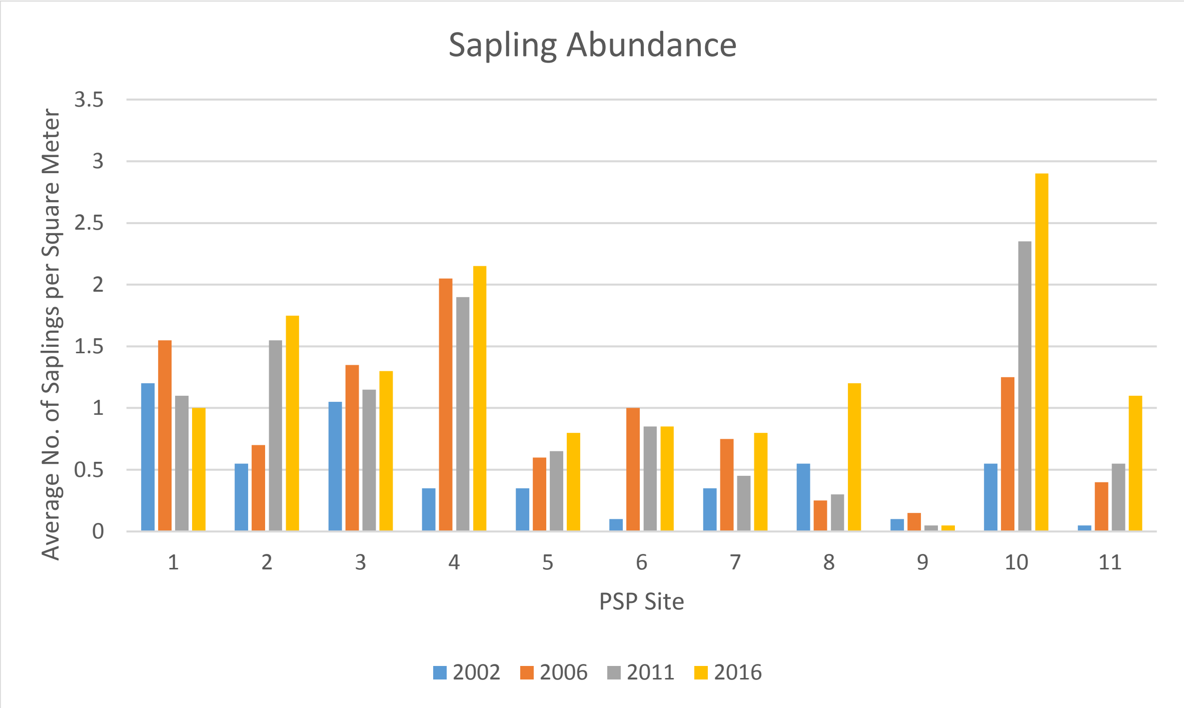

Figure 6: Sapling abundance by PSP for all the survey years

For the most part the number of species present shown in Figure 7, each PSP has remained stable or has increased, with only 2 sites showing an overall drop excluding fluctuations between survey years. Both PSPs 5 & 6 have shown increases despite the heavy browsing. PSP 9 still only has the one species present, with only one sapling in the all the subplots. The two PSPs that have shown an overall drop (1 & 3) have followed a similar pattern with an increase from the initial year to the 2006 survey before dropping off.

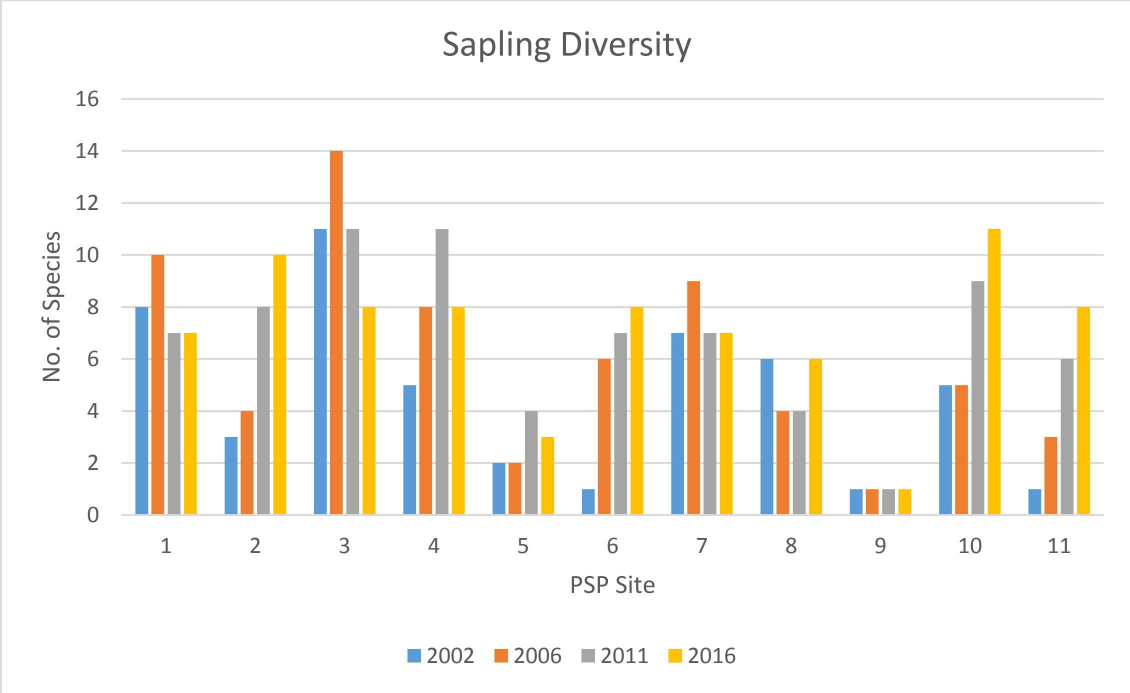

Figure 7: Sapling Diversity by PSP for all survey years.

Palatability is one of the indicators of pest browsing on a site and is visible in the survey results, with palatable saplings shown in Figure 8. PSPs 5 & 6 have low numbers of palatable species. PSP 5 has an increasing count of saplings, but only limited to 3 species of which next to none are palatable which is an indicator of high browsing. This is backed up by PSP 6 which is located close by, while this site does have increasing sapling numbers palatable sapling numbers are dropping. This is also an indicator of high browsing resulting in the spread of unpalatable species within the understory. PSP 9 has the worst sapling understory with one palatable sapling in the sub-plots that were measured. This one sapling is palatable but has no branches below shoulder height as the goats have browsed anything palatable to them.

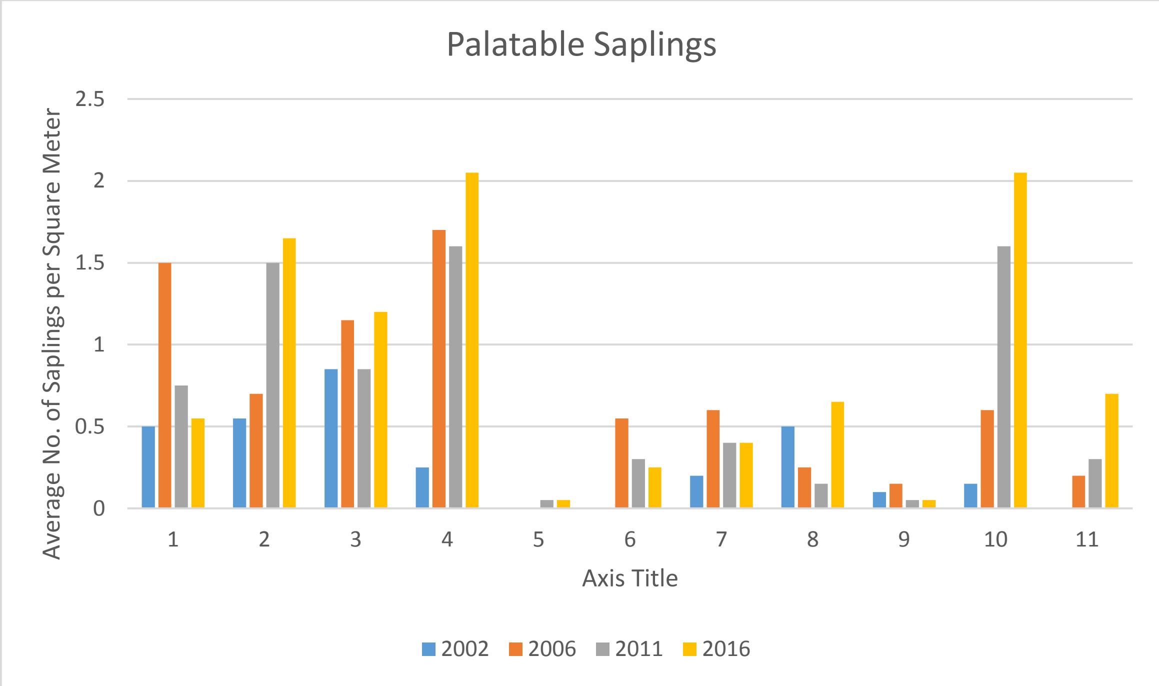

Figure 8: Average number of palatable saplings over all survey years

The sapling ordination (Figure 9) is showing the total composition change between the 2002 and 2016 survey results for the sapling layer. With several large changes in floristic composition over the 14 year period. As with the seedling ordination PSP 4 has seen the most change with regeneration producing a thick understory. Despite the large changes seen in the sapling counts and diversity for PSP 10 the change shown by the ordination if much less than PSP 4. Indicating that is has retained more of its original species present in the 2002 survey than PSP 4 which has a larger overall shift in floristic composition.

PSPs 5 and 6 are very close to each other, from the ordination PSP 6 has changed over twice as much as PSP 5. This indicate that the increase in sapling numbers and species has mainly come from species that have been introduced to the site post-2002. Species that are less or non-palatable to deer which are able to grow which less hindrance on the site.

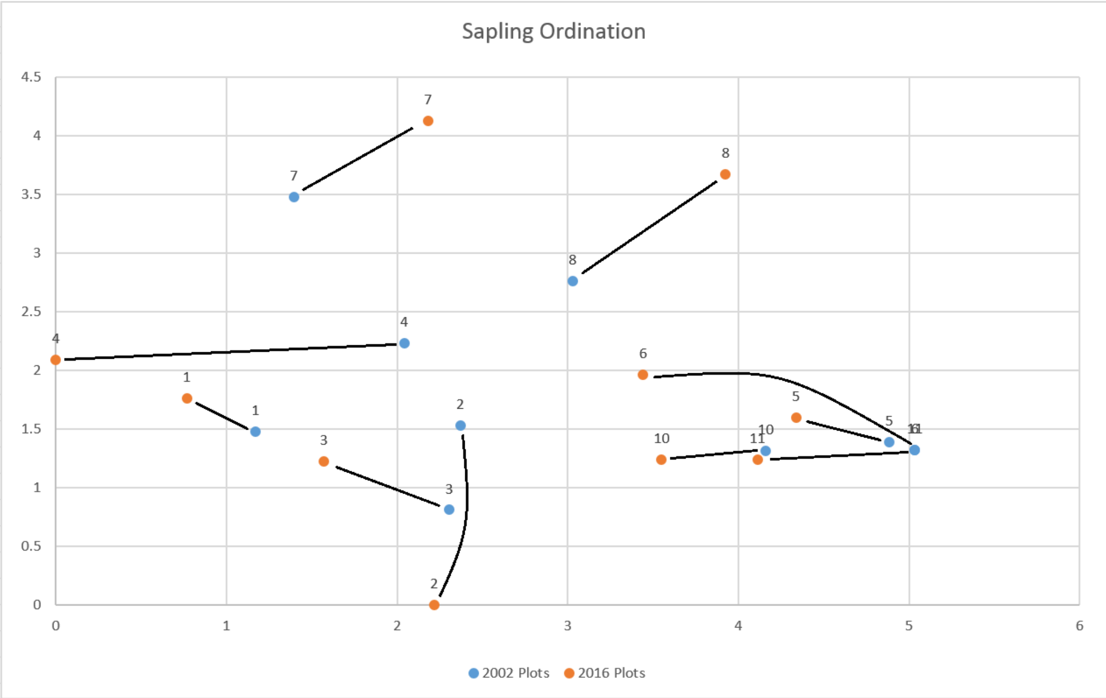

Figure 9: Sapling ordination by species between 2002 & 2016

From the results of the survey the sites which are showing good improvement in the sapling understory are 2, 4, 10 & 11. These PSP have had increases in count, species and maintained /increase percentage of palatability. This indicates that more palatable species have been moving into the remnants and are not being browsed out, this is a good sign for the recovery of the native remnants that these PSP are located in.

5.4 Canopy

After inputting and processing data collected on the plot sheets, the data collected from the 2016 survey has shown a continuation of the trends shown back in 2011. Looking at the canopy count which was the only part of the canopy data collected that has been used before in past analysis. There have been very few shifts with the established canopy trees in all of the 11 PSP, the largest increase in count has occurred at the Papa Rd PSP3 with a large number of smaller trees growing above the 10cm minimum DBH to be included in the canopy layer. While other sites have had fluctuations then have been small with older trees dying out and new smaller trees taking their place. The only major drop that has occurred has been at PSP 3 with windfall occurring across one end of the plot, this resulted in several trees being toppled.

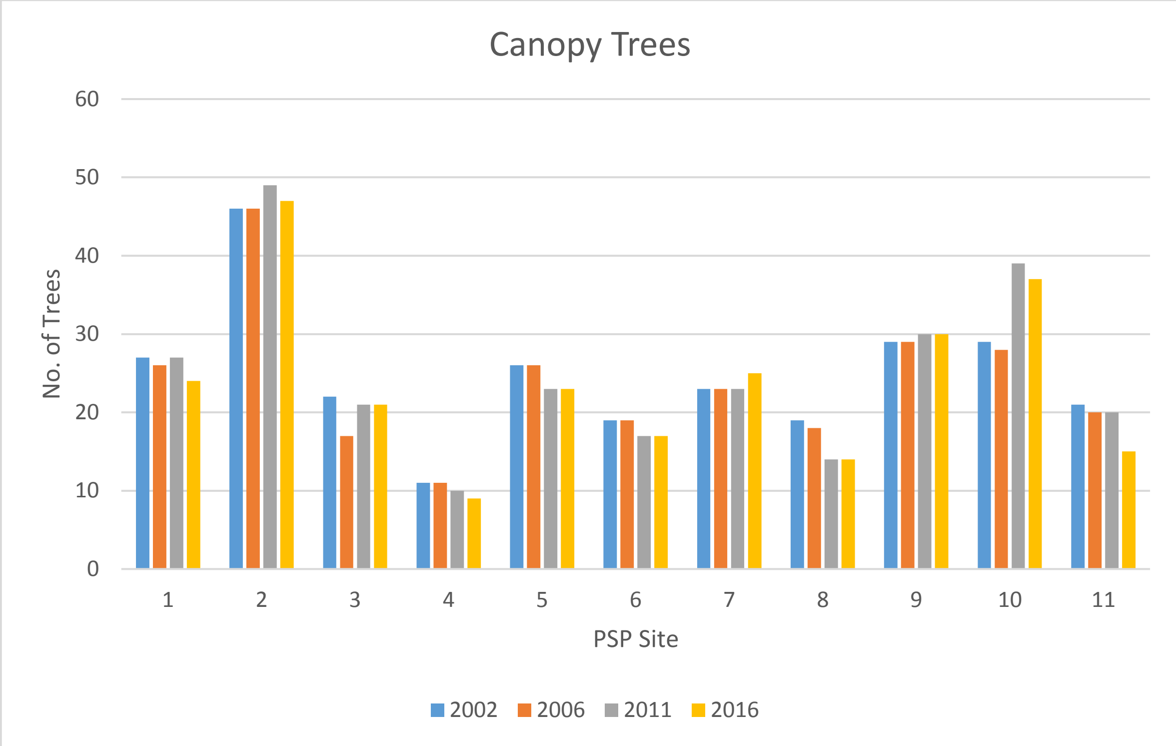

Figure 10: Canopy tree count for all survey years

As the DBH of all of all the canopy trees has been collected across all of the survey years the basal area has been able to be calculated for each plot. Basal area a good measure for growth of a native forest and is able to show total growth better than looking at average DBH growth across each plot. Even though there have been drops in the canopy counts in several of the PSP there have been steady increases in BA between 2002 and 2016. The plot to be most concerned about PSP 6 with both decreases in count and BA over the period. This could become a concern in the future if the understory layer is continued to be suppressed by high deer browsing, which could prevent new canopy trees from forming/growing through. Although this could become a concern the other PSP 5 being located close by (100m) which could mean that the results are very local. But the very low palatable saplings at PSP 5 and rapidly dropping numbers at PSP 6 are showing that succession may become a problem in the future. These results are comparable with studies in the area which have concluded that der browsing has effected the regeneration cycle in beech forest in the area (Allen & Allan, 1997).

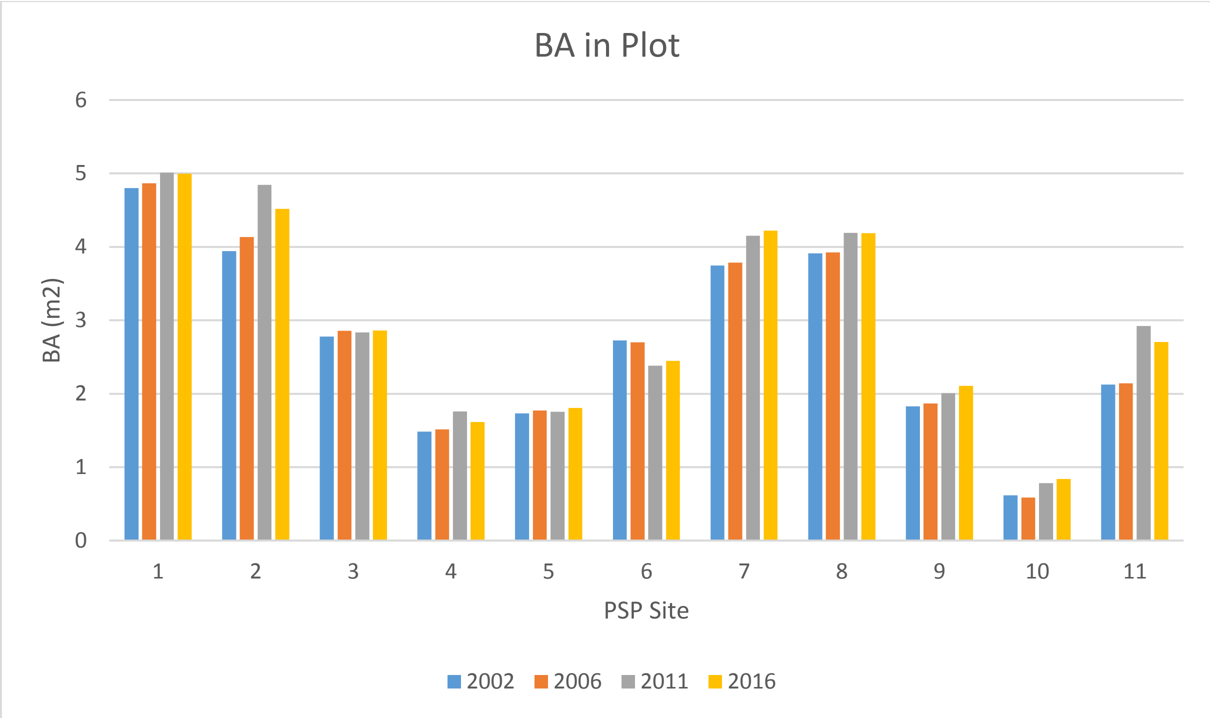

Figure 11: Canopy basal area (BA) for all survey years

As with the seedling and sapling analysis I have looked to the ordination to provide a more detailed explanation on how the canopy has changed over the monitoring period. As before with the overall BA there is very little change shown by the ordination even though the BA was broken up by species for the analysis. With the majority of the 2002 vs 2016 plot points being right on top of each other or very close by. One thing to note it that there are three distinct grouping of the ordination points, they mark out the three main native forest types.

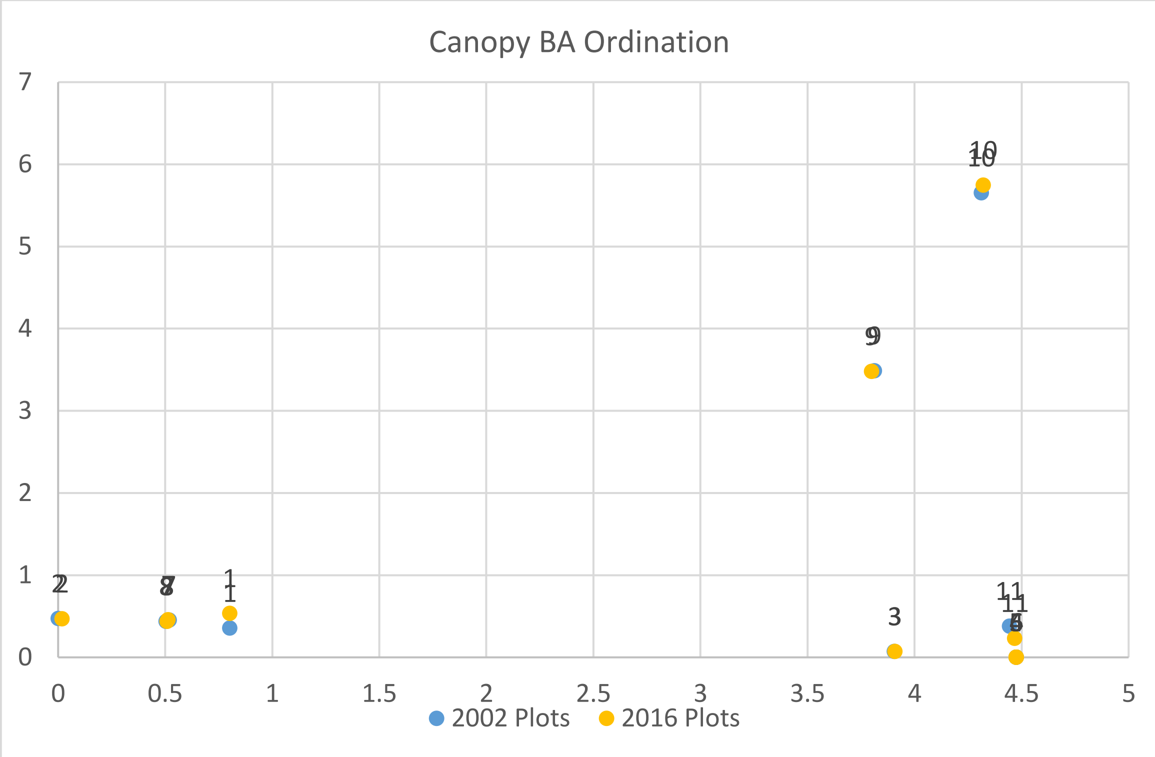

Figure 12: Canopy basal area ordination between 2002 & 2016

Figure 13 shows that there is no correlation between the canopy layer (as expressed by basal area) and the seedling or sapling numbers seen in the understory layers. The highest R^2 value calculated out of the four figures was 0.177 which is very low and shows no correlation between basal area and palatable seedlings, as was the case for all of the other correlations. With no correlation there must be other drivers affecting the understory across the monitoring period apart from the current composition of the canopy layers. This driver is likely to be pest browsers which have been suppressing the understory layers.

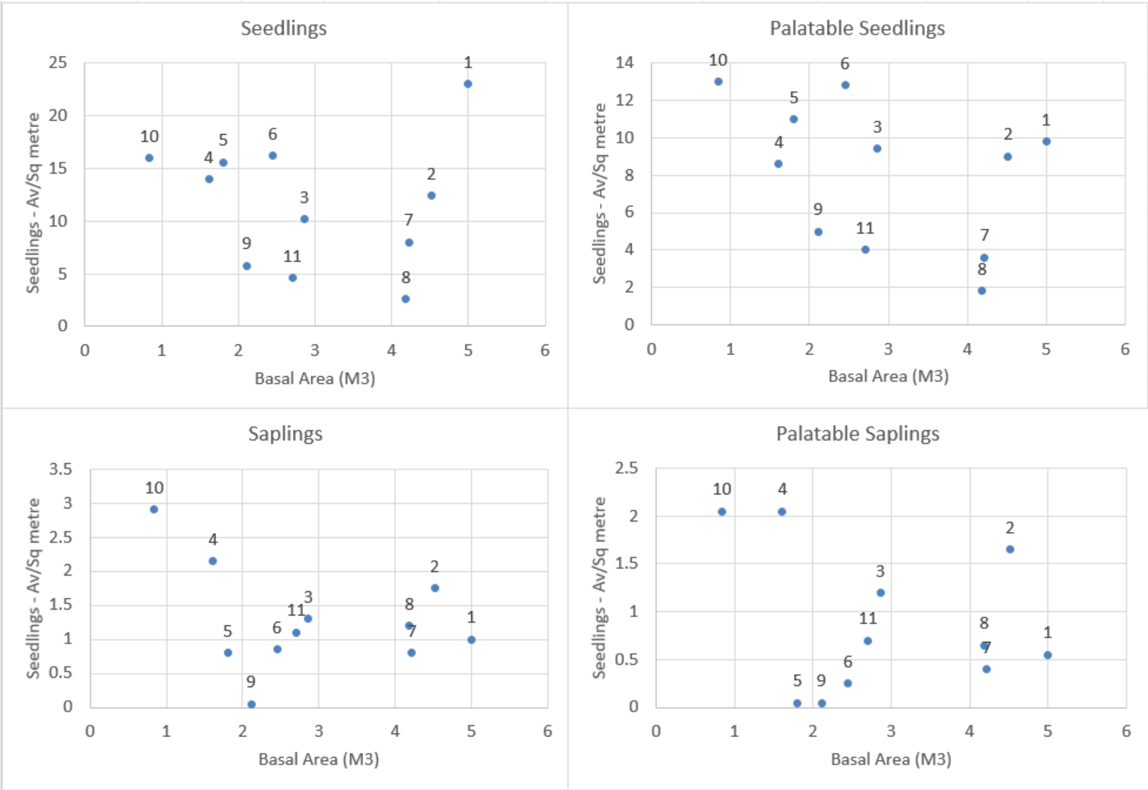

Figure 13: Correlation of canopy basal area vs seedling & sapling numbers

5.5 Representativeness of the PSPs

In order to assess how representative the 11 PSPs are of all the remnants in the estate I looked at a classification the native forest based on current canopy composition (Pan Pac, 2016). The PSPs cover a total area of 0.44ha compared to the entire 4709 ha of native vegetation, so 0.01% of the total native vegetation in Pan Pac's estate. Table 3 shows the current native areas under each classification and the number of PSP that are located in that forest type.

Table 3: Plot remnant comparison

Native Vegetation type	**Area (ha)**	**No of PSPs**
BEECH	273.8	3
BEECH/PODOCARP	54.8	2
KANUKA/MANUKA	1825.3	0
ANGIOSPERM	1311.7	2
MIXED/KANUKA/MANUKA	1031.7	1
NVEG/REGEN MIX	10.6	0
PODOCARP	118.6	3
WETLAND	48.3	0
Unclassified	34.4	0
Grand Total	**4709.0**	**11**

The monitoring plots are not representative of the full range of forest types present, with ANGIOSPERM and KANUKA/MANUKA forests types having disproportionally low PSP numbers when compared to beech forest. A case could be made for not monitoring KANUKA/MANUKA scrub as this could be seen as a waste of time because of the more uniformed nature of the bush. However, this forest type will regenerate to other taller forest types in time, so it would be worth monitoring. But there should be more PSP sites in ANGIOSPERM remnants considering they cover over 1300ha of forest and only have two PSPs. More monitoring of both of these forest types would result in a more representative monitoring program of the current remnant estate.

6. Discussion

6.1 What information does the data that has been collected provide?

6.1.1 Understory: Seedlings and Saplings

Seedling and sapling counts by species provide the base information for the understory analysis of each of the PSPs. From this information we can assess how the understory plant composition has been changing between each of the survey years. The understory has been greatly affected by pest browsing which can result in the suppression of growth in this layer. There has been a large amount of variation in the seedling results from each of the PSP sites which could be attributed to this browsing. But this could also be attributed to observers or small differences in the of years each of the surveys would of been conducted. It would be hard to pin this down without a more in-depth monitoring program with multiple observers doing the same plots for a comparison.

There is a distinctive difference between the seedling and sapling counts diversity and palatability on several sites. Natural reductions in numbers will be seen as not all seedling will be able to populate the sapling layer without some dying from competition. But on the sites with high browsing there has been a distinct drop in numbers of palatable plants between the seedling and sapling layers. While the seed source is present to repopulate the seedling layer, palatable seedlings are not able to grow and repopulate the sapling layers because of herbivory. This is causing a shift in understory composition which results in a non-palatable understory developing.

While slow change in the current understory due to browsing is not currently effecting the canopy layers of the PSPs it could in the future. The seed source for the current understory comes from the canopy layers, if this seed source dies out and the browsing continues the understory which comes up to replace the canopy layers could change. This will result in a larger over all shift in the type of forest present. While this would be a long way off it is still likely if the impact of browsing of the understory layers is not reduced in the future.

6.1.2 Canopy Layer

The canopy information that has been collected up until this point has allowed a picture to be built up about the canopy composition of each of the PSPs. The summary graphs as well as the ordination analysis completed on canopy BA show there have been very little change from 2002 to 2016. This is expected and is mainly due to the slow growth of canopy layers of the native forest remnants. The disturbance based regeneration of native forest (Hill & Read, 1996) results in the canopy layer suppressing the understory until gaps open up and more light triggers saplings to fill the gaps that have been made.

Despite the slow growth some smaller changes have started to occur with drops in BA as well as canopy tree counts. These are happening on sites that have had high pest presence noted across the surveys. This has been partly due to wind-throw in particular areas or other individual trees dying out. While these may be short term drops, only long term monitoring will be able to show if it is short term or a longer term downward trend in BA if the canopy is not replaced from the understory layers.

While there is little change in floristic composition being shown compared to the other layers of the forest, the canopy has changed over the survey period. While the changes are small this could be altered if there is a large disturbance event in the canopy layer such as a snow damage. This could open up for the understory to start replacing the canopy if the sapling are there to do it. The biggest issue is that the suppression of the understory could result in more non-palatable species coming through resulting in a change in the canopy's composition in the longer term.

6.2 What does the monitoring tell us about the remnants in which the PSP are located? How have they changed over the monitoring period?

Looking at the results of the ordination analysis on the understory data collected on the PSPs it is clear to see which of the remnants appear to be regenerating. When you compare the results with information on the pest presence at each of the sites you can see a correlation between low pest presence and the changes that have been occurring. In the past high pest browsing has suppressed growth in the understory across several sites, mainly around palatable species present. Below is a summary of where I believe each of the sites it at currently:

PSP 1 – Wakarara Rd

PSP 1 has remained relatively stable over the 14 year monitoring period, its seedling layer has seen improvement in both numbers and species present with the sapling layer remaining stable. Despite this there have been drops in numbers of palatable saplings which have been hard to understand. This is because of no pest presence observed in or around the plot, no faecal matter, browse damage or sign. The area is very wet and dark making it an unlikely place for deer to stay for long periods of time. But overall the ordinations have shown only a small change in the seedling layer, slightly more in the sapling layer. More monitoring and investigation would be needed into this site to understand why this change is occurring.

PSP 2 – Pickford Rd PSP 1

PSP 2 indicates that this part of the remnant it is located in has experienced good growth, with increasing numbers and species in both the understory layers. The numbers of palatable seedlings have increased slowly over the survey years while there have been considerable increases in palatable sapling numbers. Deer browse damage was observed on the site but was having little impact on regeneration. Several trees have grown into the canopy layer in the last 14 years with reasonable BA increases. I believe that this PSP is in good health as well as the surrounding native remnant. Further continued monitoring of this site will indicate if the good growth will continue, level off or decline.

PSP 3 – Pickford Rd PSP 4

PSP 3 is located around 500m from PSP 2 but has a distinct compositional difference being located on a slope in a more shaded area of the larger remnant. The canopy layer in the PSP has had fluctuations but has had a slow increase in BA over the monitoring period. Palatable sapling number have increased over the years but the seedling layer has peaked in 2011 before dropping back to the 2002 levels. This is linked in with the drop in 2 species present on the site. Despite this I believe that over all the remnant/PSP is stable with a strong sapling layer to replace any gaps that occur in the canopy layer in the future. As before further monitoring of both Pickford road site are important to insure continued stability of the remnant into the future.

PSP 4 – Wakarara/Ellis Rd

PSP 4 has shown the most overall change in understory composition through the monitoring period, with both the seedling and sapling ordinations showing large movements. Sapling numbers have greatly increased and although diversity looks like it has peaked this remnant shows good regeneration. The seedling layer looks steady having adequate numbers and species present, although seedling palatability is dropping. This is not reflected in the sapling layer with palatable numbers increasing year on year and remaining very high. Canopy tree numbers have dropped but BA has continued to increase, with the thick understory replacement of the canopy layer is nothing to worry about.

This is the most promising PSP/remnant for understory regrowth, but there was deer browse observed in the seedling layer so it will be important to keep the deer population in check in the area. Walking through this site is it clear that the regeneration is coming through strongly making it hard to move around the site.

PSP 5 – Castle Rock Rd PSP 3

This PSP has the second worst sapling layer out of the PSPs studied, although sapling numbers are increasing, palatability of this layers remains below 10% with very few numbers present. This indicate high browsing from pest resulting in the spread of non-palatable species throughout the remnant. Seedling numbers, diversity and palatability look good but these plants are not reaching the sapling stage and growing to a size where they become less effected by pest in the area. There has been little overall change in the seedling layer over the past 14 years, this indicates a good seed source for the moment. A reduction of pest numbers is needed in the area to allow the remnant to regenerate and replace the canopy layer in the future. This site would be a prime candidate for an exclosure plot to measure the potential regrowth of the forest after pests are excluded from the plot.

PSP 6 – Castle Rock Rd PSP 4

PSP 6 is located 500m from PSP 5 in a large beech remnant in Kaweka forest and both are indicating a similar pattern. With high deer browsing causing the potential degradation of the whole remnant if pest numbers are not reduced in the near future. The canopy tree numbers have reduce in the plot with several dying out resulting in a drop in the basal area for the plot. Sapling numbers and diversity have been increasing with each survey but palatability has dropped each time. I believe this indicates the browsing pressure caused by the deer is causing a shift in composition to less palatable species. With non-beech species making up the sapling layer there are fewer trees that could replace the gaps from dying canopy trees. This area is more advanced in the transformation process than PSP 5 and is an indication of what could happen to the while remnant if pest numbers are not reduced. Both PSP 5 & 6 are experiencing similar trends, this has been backed up by a study on beech forest in the Kaweka ranges close to the site (Allen & Allan, 1997). Pest control would be difficult on the site but could be possible with the correct methods.

PSP 7 – Takere Rd

PSP 7 is a relatively stable site for both number and species present for the whole understory but has seen a shift in composition shown by the ordination. New species have been introduced into the plot and other species have died out. Browse damage and faecal pellets from deer were seen in the last survey indicating a pest presence but there has been no estimation of numbers making it hard to understand the changes that have been occurring. For this site believe that further monitoring is required and pest reduction may improve the remnant overall.

PSP 8 – Paratu Rd

PSP 8 is another site which it has been hard to pick out any trends in the understory growth. The canopy layer has had a small drop in tree numbers but has had increased BA over the survey years. There have been big fluctuations in the seedling layers diversity and palatability with very low numbers being the likely issue. Sapling numbers have increased and diversity remained equal over the 14 years but there were drops in the 2nd and 3rd survey years, combined with a drop in sapling palatability from high (95-100%) down to medium (50-55%) in later years but overall number are low which makes the result hard to interpret. This could indicate a transient deer population browsing on the remnant at various point. Deer browse and faecal pellets were common so targeted pest control in the area around the remnant might be a possibility if the population could be tracked.

PSP 9 – Karaka Rd

PSP 9 has had one of the smallest changes in composition of the seedling layer, this is very apparent when visiting the site because of the goat browsing. This would have also been reflected in the sapling ordination if the only species present was related to any of the other PSPs. The sapling layer is non-existent with no seedling being able to mature. This suppression of the understory will lead to a change in canopy layer composition if any regeneration occurs at all. Current canopy tree numbers are remaining steady and BA is increasing but this could change in the future if the goat population in the area is not reduced. Harvesting is currently taking place in the area which will include intensive control of the goat population, this should help but the goat population needs to be reduced in the long term to have a lasting effect.

PSP 10 – Papa Rd PSP 3

PSP 10 has shown the largest increase in sapling abundance over the survey years out of any of the sites studied, along with a good increase in species numbers present on the site. The seedling layer has followed a similar pattern but has reduced from the 2011 to 2016 surveys, likely due to suppression of seedling by the sapling layers. Palatable number present in the sapling layer has remained high over the period but has declined in the seedling layer in line with the other reductions. Although these changes shown in the summary graphs are in line with those seen in PSP 4 there has been a difference seen in the ordinations, with PSP 10 only shifting half a much in composition between 2002 & 2016. This shows that the species present are more uniform between the ordination years. The number of canopy layer trees is increasing along with total BA in the PSP. Overall this PSP indicates the remnant is in good health and should continue into the future if pest number are kept low in the area.

PSP 11 – Papa Rd PSP 4

PSP 11 follows a similar trend to PSP 10 with really good regeneration of the sapling layer, as very few were present in 2002. Both numbers and diversity of the seedling layer have increased which has resulted in a reduction of the seedling layer, which has relatively low in numbers when compared to other sites. Numbers of palatable saplings have increase over the course of the monitoring program. There has been more composition change in PSP 11 than PSP 10 which has been shown in the ordinations. There has been a relatively large drop in canopy tree numbers when compared to other sites, but this is due to a recent snowfall causing damage to several trees at one end of the plot. BA is higher in 2016 than 2002 despite the damage resulting in several trees toppling. As with the other Papa Rd site pest numbers should be managed to remain low to aid in understory regeneration.

This is my current assessment of each of the PSPs which are a representation of the remnants in which they are located. This has been put together from my assessment of the data that has been collected in the pest and the review of associated literature I have carried out.

6.3 How can the monitoring programme be improved in the future to better meet FCS requirements?

Based on the results of the monitoring presented here it would seem that there are three sites that require more focused pest animal management in the future. These have been outlined in the section above and I believe if they are acted on it will result in Pan Pac better meeting their FSC requirements for native forest monitoring as well as their environmental goals in general. If these steps are not taken the sites could deteriorate in the future, this process will take time but could result in a large change in forest composition in these three native forest remnants. It will be important to conserve these remnants into the future to maintain areas that reflect a proportion of what the original land cover looked like. To best target pest control to improve the remnants it would be worth establishing enclosure plots to see what the effect of excluding pests such as deer from an area would be. This would allow for the assessment of regrowth and the potential benefits that reducing pest populations in an area would be. My recommendation would be to install two exclosure plots, one at a site where deer are having an impact and one at a site where goats are having an impact.

It is clear that there should be an increase the number of PSPs to cover more of the 4,600ha of native forest in the estate. More PSP covering other remnants would provide a better idea of how the remnants are changing and result in better targeting of management practices. The establishment of four more PSP sites would allow for a better coverage of the remnants in the Pan Pac estate, focusing on the podocarp/broadleaf forest type. One of the sites that defiantly should have a PSP is the Burbury Rd remnant, which has shown good regeneration after the goat population in the area had been reduced. While access to the site is difficult because of blackberry growth it would still be a good use of time to monitor the site in more detail. While the exact effect of the removal of goats cannot be measured if monitoring did start today, the continued regrowth can be measured which could help with the analysis of other remnants in the future.

The size for native vegetation PSP is 0.04 ha which is comparable to other programmes, but methods for collection are different. The current method works for Pan Pac and while switching would allow for a comparison to other PSP there would be no accurate comparison that could be done to the data that has already been collected. The continuation of the current monitoring method is the best option as it is currently working, but improvements could be made in the future with the inclusion of exclosure plots and the creation of new PSPs in the native estate.

Better/more detail around what management practices that are occurring around the remnants, especially in regard to where pest control is occurring would be helpful for interpreting patterns that are apparent from the monitoring. While there is possum control throughout the forest, larger animal pests such as deer or goats are controlled through shooting, with only general records are kept. More detailed records would allow a better assessment of what or if any of the management practices are having an effect on the remnants, for better or worse.

I believe that the native forest monitoring programme does fulfil the requirements under the FSC criteria and guidelines, but it can be improved. Management activities have been carried out in surrounding forests to reduce pest numbers in the past. But this should be targeted more specifically in and around native remnants, especially the PSP's 5, 6 & 9 that have been identified at slowly deteriorating. The native forest monitoring programme was originally set up to identify and track how these remnants were preforming, improvement have been shown in several sites (2, 4, 10 & 11) but others are changing composition due to excessive pest browse. The programme should be continued in the future to keep a record of the composition of the native remnants in the estate and to track the changes that management practices and pests are having on them.

7. Limitations

-The results of the native forest survey cover a short time frame when looking at native forest growth, with the original native forest cover being established over a much longer period. The monitoring needs to be continued into the future to gain a better understanding of changes in composition. I believe that the current 5 year monitoring cycle is the correct length of time, a shorter length would result in an excessive expenditure of time and not yield any further information. If the time was extended out beyond 5-years the surveys might not catch the fluctuations seen in the current results.

-I have found issues with some of the previous data collected for the previous native forest surveys. This has been with the entering of the data into Excel from the original plot sheets used out in the field. This was combined with the miss-identification of some of the recoded species in regard to their palatability. To solve both of these issues after discovery I went back over all the original plot sheets, rechecked and re-entered the data when needed. Reliance of previously collected data can be a risk but I do believe that the errors only arose through entering the plot sheets into Excel as the original surveys were conducted by Matt Hansen and Wendy Prescott who both specialise in native conservation and completed most of the classification of Pan Pac native forest remnants.

- Lack of specific detailed management practices in and around native remnants has made it impossible to relate any specific plantation forestry activities into the results from the survey. While it is known that animal pest control has been carried out on several of the sites over the past 14 years it has been difficult to find information on exactly when and where this has been carried out. If larger pest control programs are going to be conducted in the future, assessments of pest numbers should be made pre and post-operation especially in the surrounding native remnants. This combined with assessment of browsing in the remnants would give a better understanding of the effect of pest control. Compared to just the visual inspections that have been done in the past at Burbury Rd site.

- While the PSPs do give a good representation of the remnants they are located in they only cover small sections of each remnant, and the whole native estate as a whole. As it is impossible to cover the entire estate the best way to build up a picture of is there is through sampling. Correct sampling is key and I do believe that four more PSPs should be established to cover more of the estate, both in terms of a better representative sample as well as to cover more of the 4,708ha of native forest.

-One of the big limitations or challenges in the near future with the monitoring and restoration program will be working with local Iwi in deciding on management activities. Currently two of five large forests that have previously been under Crown ownership have been given back to local Iwi after settlements. With this change in ownership there is a change in permitted activities, in the past under CFL companies have been able to do what they wanted with the land but now are limited to operations related to the management of their plantation forests. This results in Pan Pac not having the mandate to monitor or manage native remnants in the future without Iwi permission. This will have to be an issue raised in the near future with the owners of the land and a joint management strategy is likely to be implemented.

8. Conclusions

While the focus of my analysis has been mainly aimed at the sites that look like they are deteriorating there are sites that have been improving or remaining at a steady level over the survey period. It has been difficult to find and justify the trends seen in the data from the survey but using ordination and a review of literature on the subject has allowed me to gain a better understanding of how each of the remnants the PSPs are located in.

The main influencing factors for composition change that have been identified through the survey and analysis has been pest presence and browsing. The main indicators being the suppression of understory layers, with elimination of palatable species. In the longer term this can have an effect on canopy layers, with regeneration being surprised and a composition change occurring with less palatable species establishing. If this is not managed in the future it could led to the native remnants changing composition from their current form.

Pest control has shown to have a good effect on several remnants in the Pan Pac estate, while a PSP has not been set up at the Burbury Rd site there has been a marked improvement since the goat population has been reduced. Understory growth as returned and will allow for the continued regeneration of the canopy after future natural disturbance events. Across most of the PSPs there is continued growth of the understory which should maintain the current composition of their canopy layers. The introduction of exclosure plots would allow for the assessment of regrowth without pest presence and result in the better targeting of future pest control activities. I believe that this would be the best starting point in the near future as it will take time for the exclosure plots to show a difference in growth.

Monitoring of native forests is key to be able to identify as well as understand what is happening with any remnant in a plantation estate. Tracking composition change is important, whether it is good or bad as it allows you to target management practices to combat what changes are occurring.

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10. Appendix

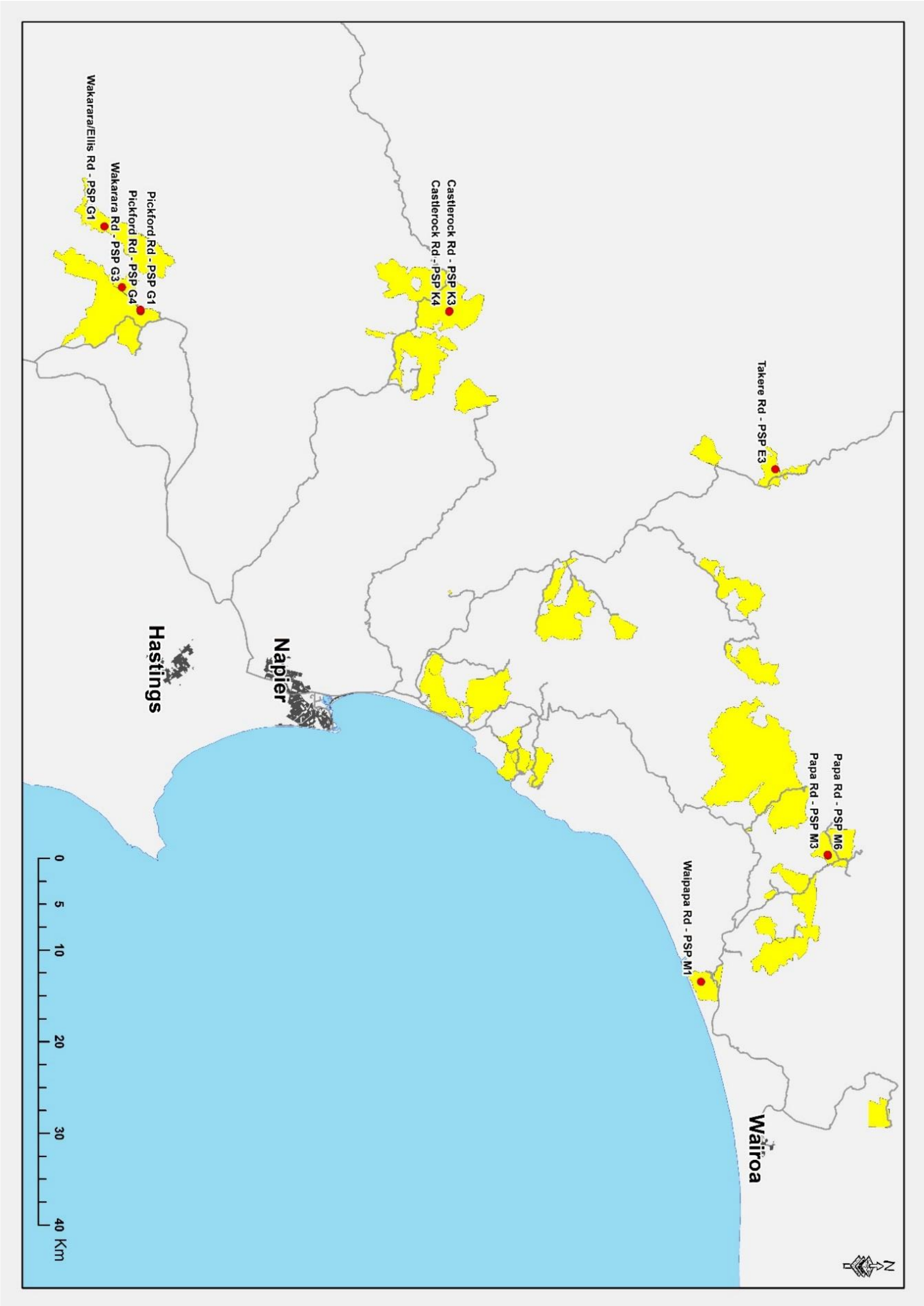

Figure 14: Map showing the 11 native remnant PSP locations

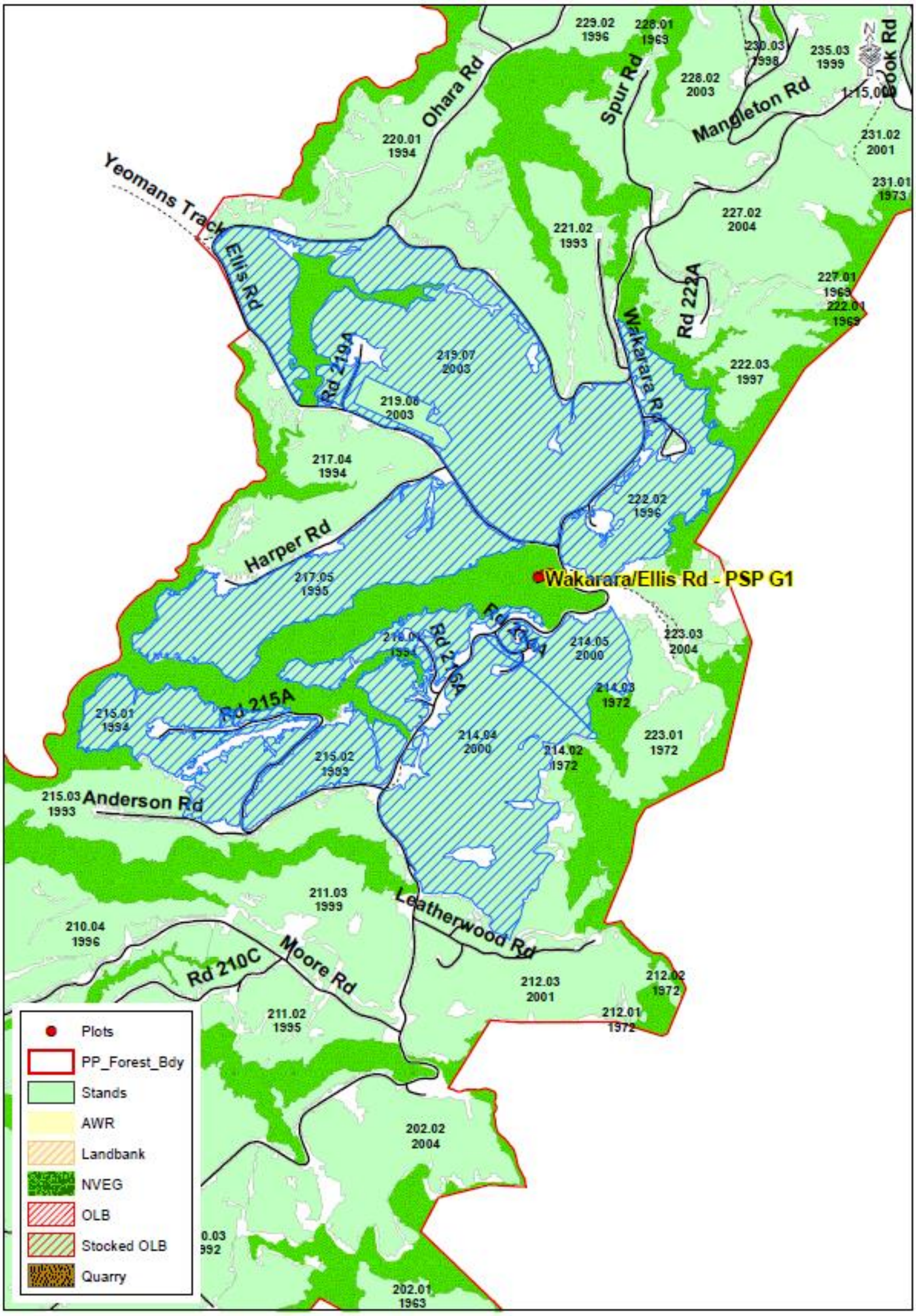

Figure 15: Map of PSP 6 Wakarara/Ellis Rd

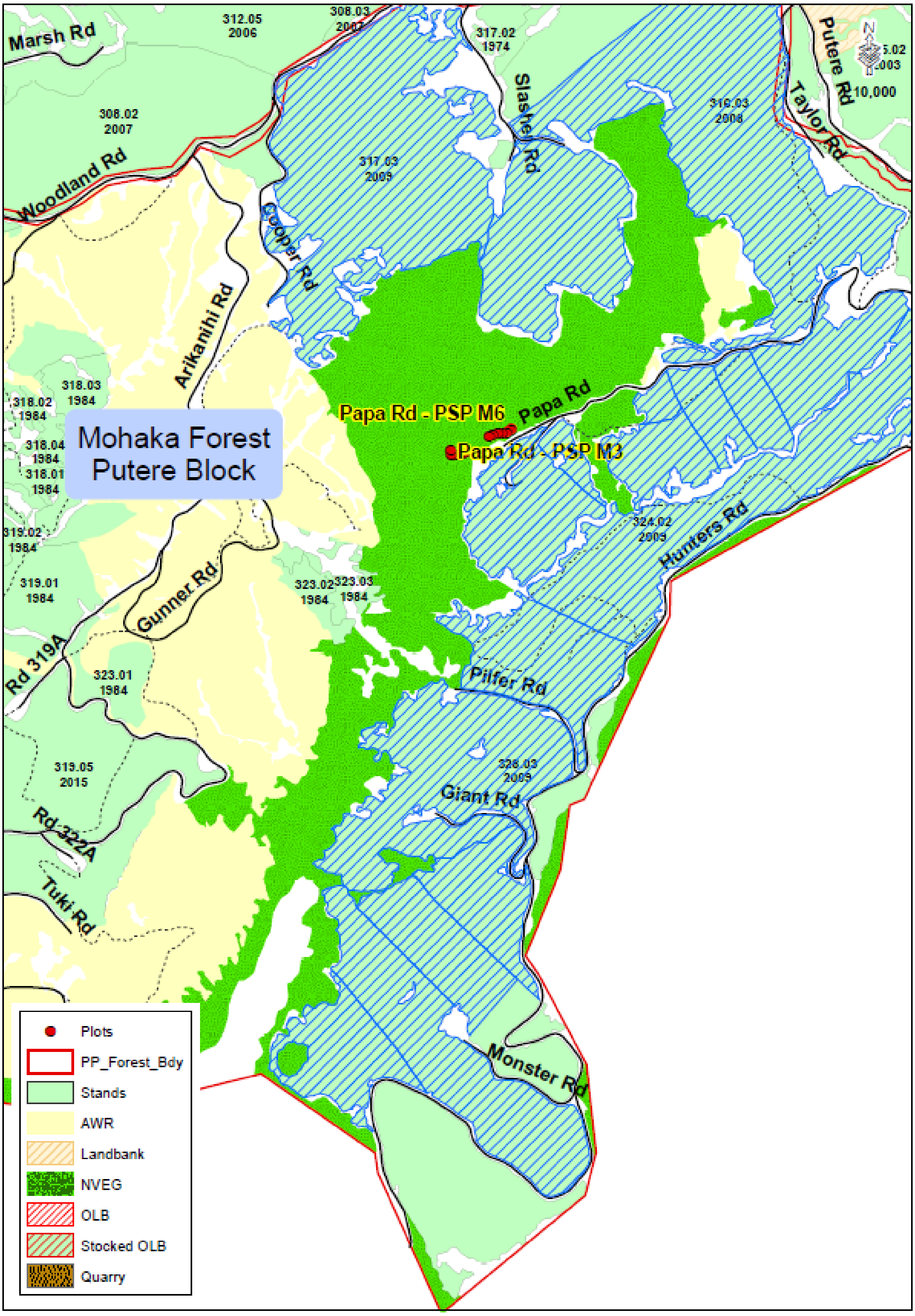

Figure 16: Map of PSPs 10 & 11 Papa Rd

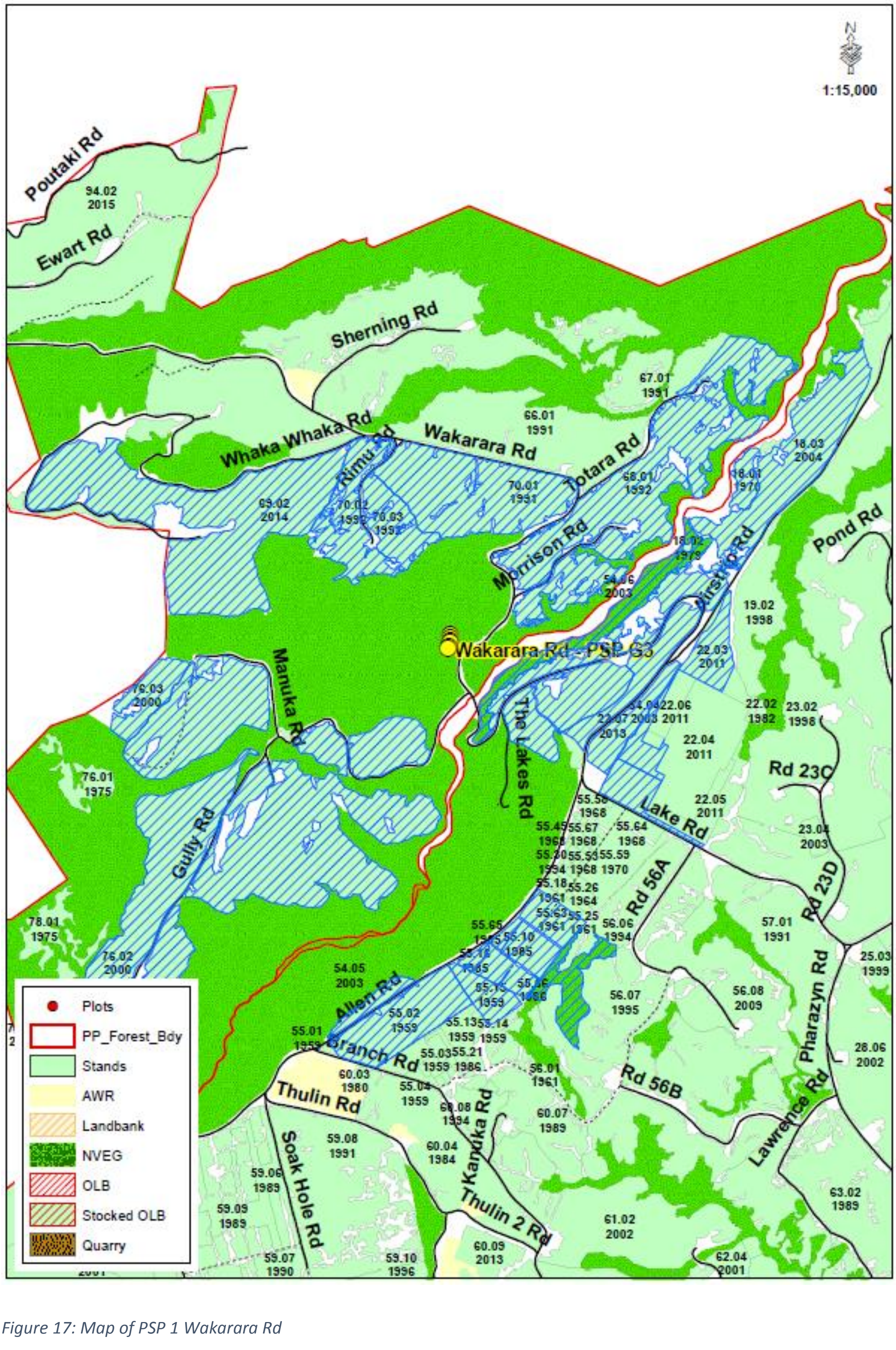

Figure 17: Map of PSP 1 Wakarara Rd

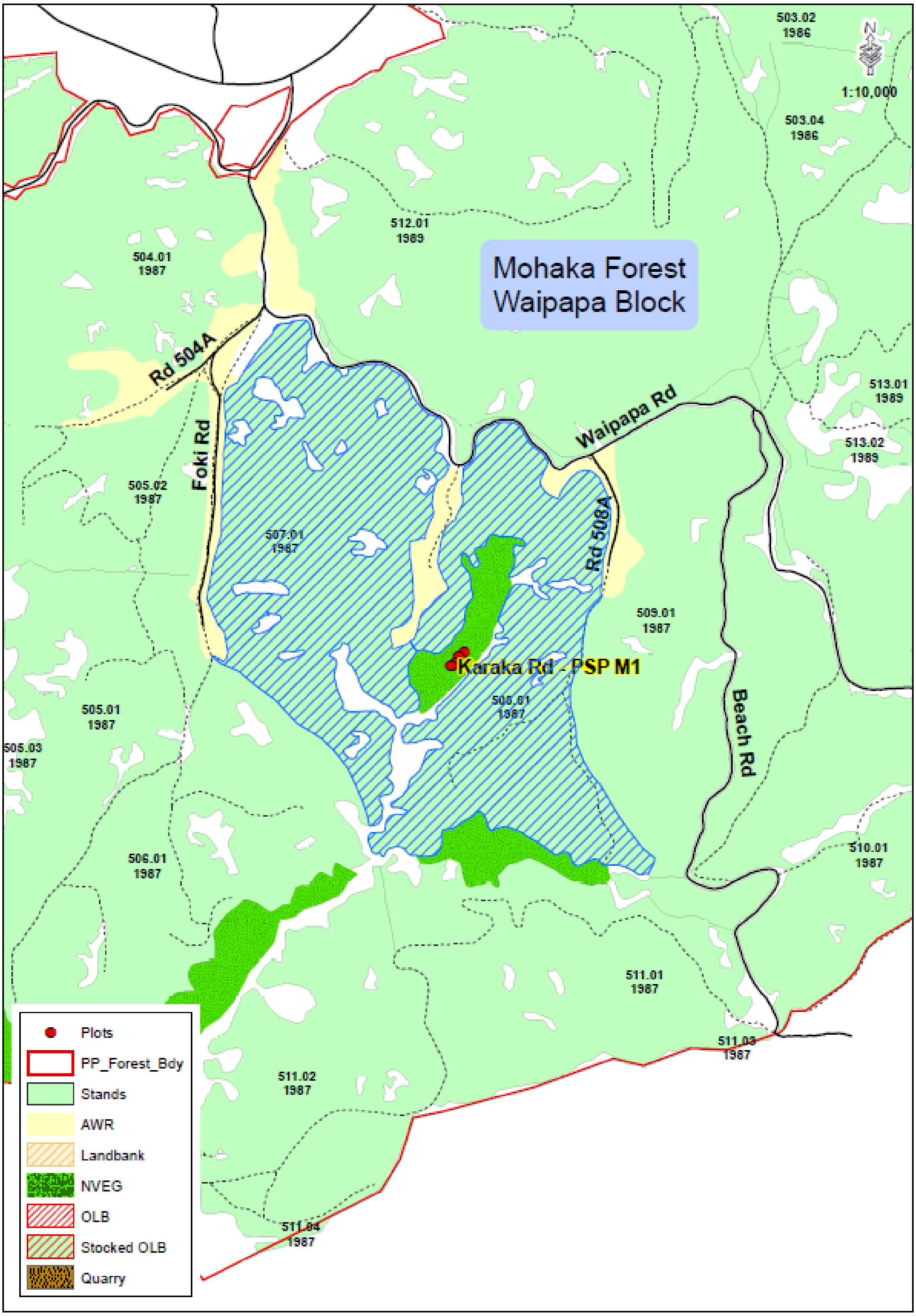

Figure 18: Map of PSP 9 karaka Rd

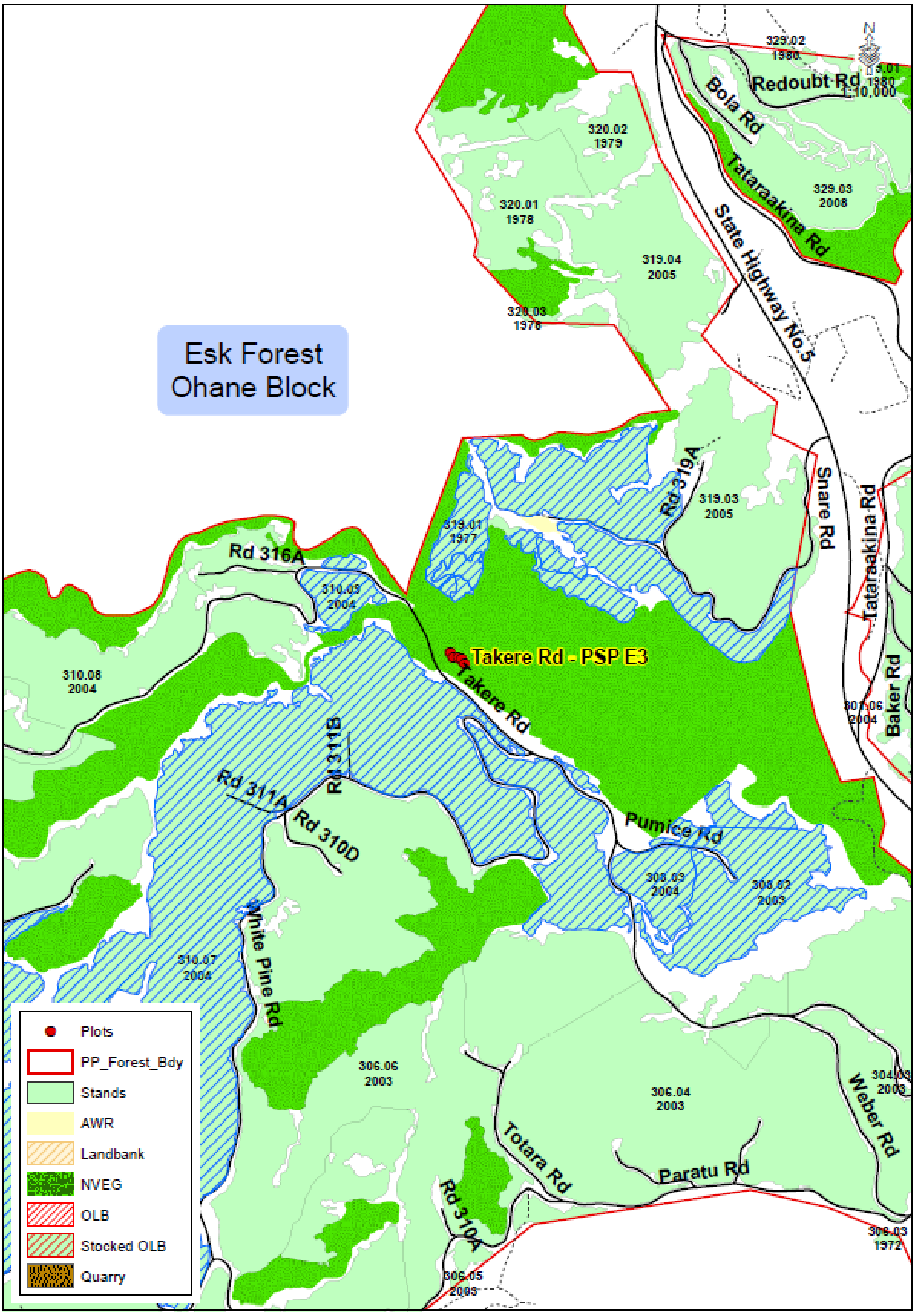

Figure 19: Map of PSP 7 Takere Rd

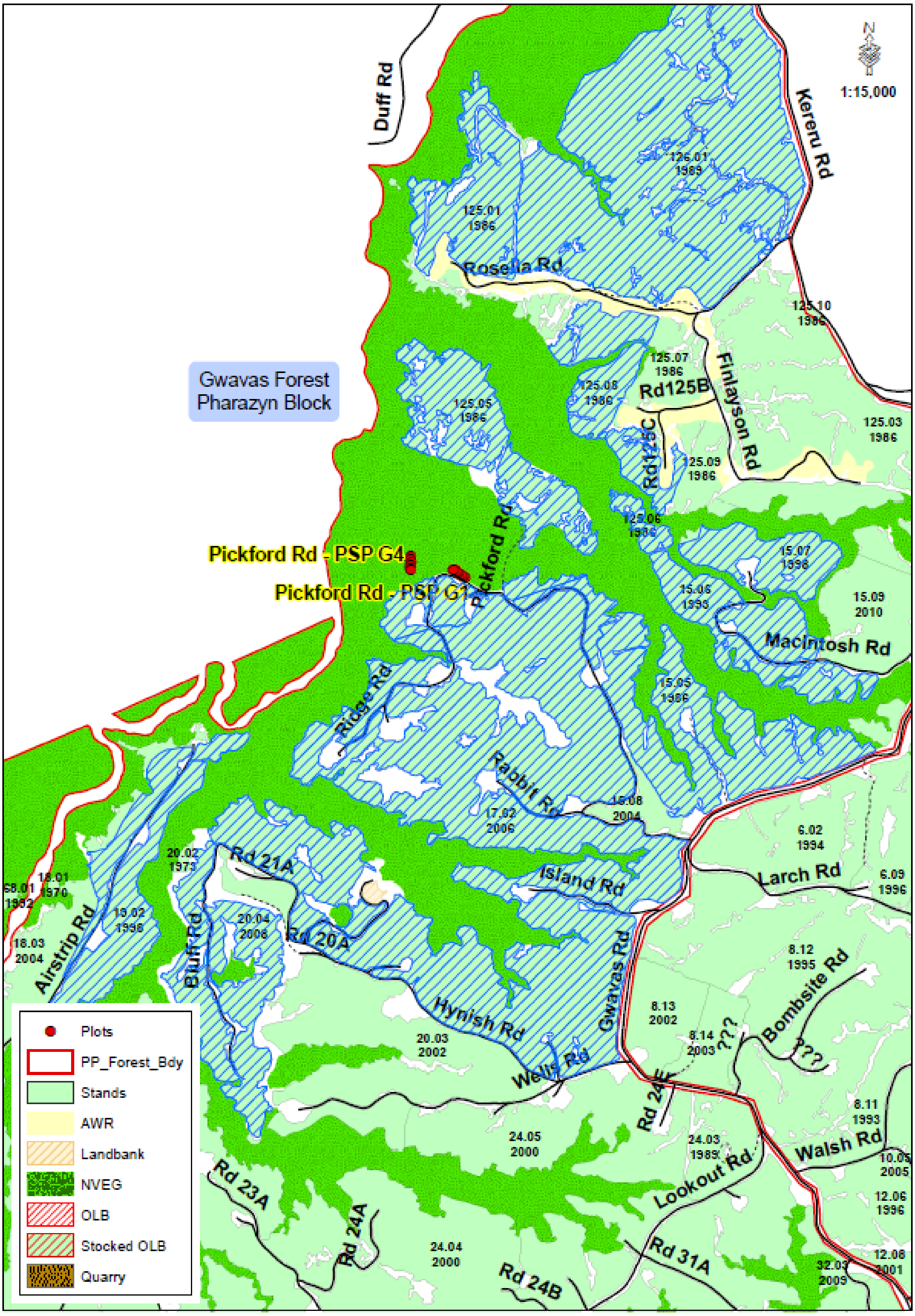

Figure 20: Map of PSP 2 & 3 Pickford Rd

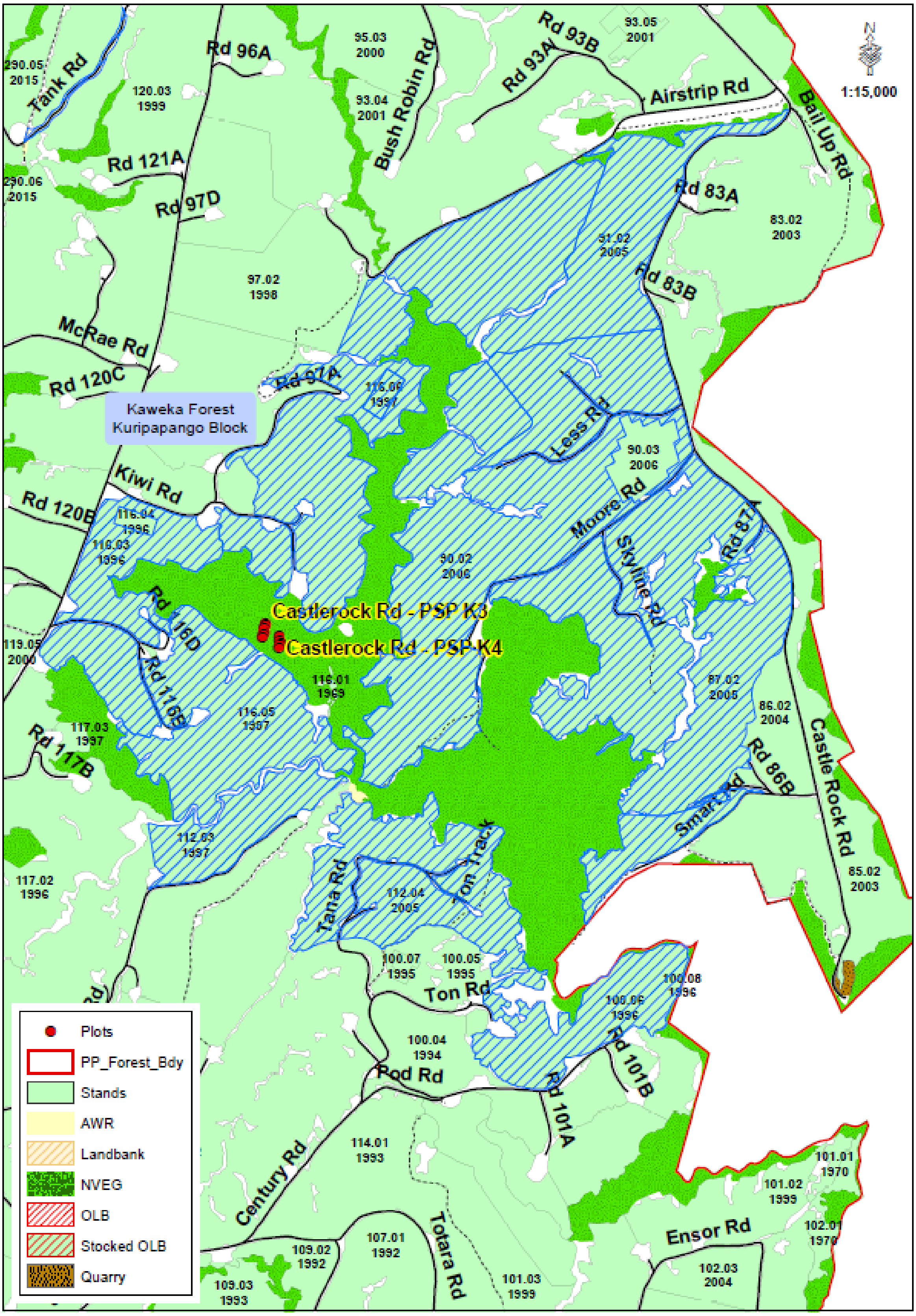

Figure 21: Map of PSPs 4 & 5 Castle-rock Rd

Figure 22: Windfall damage at one of the PSPs, one large tree has damaged and brought down several of the smaller trees creating a larger gap

Figure 23: Main centreline and subplot within one of the PSPs. A larger canopy tree supressed the understory regeneration around its base.

Figure 25: First Visit to one of the PSPs with Brett Gilmore

Figure 24: Alloy tree tag that has been overgrown since the establishment of the monitoring programme.

Figure 26: Further windfall damage at one of the Papa Rd PSPs

Figure 27: Subplot measurements at one of the PSPs